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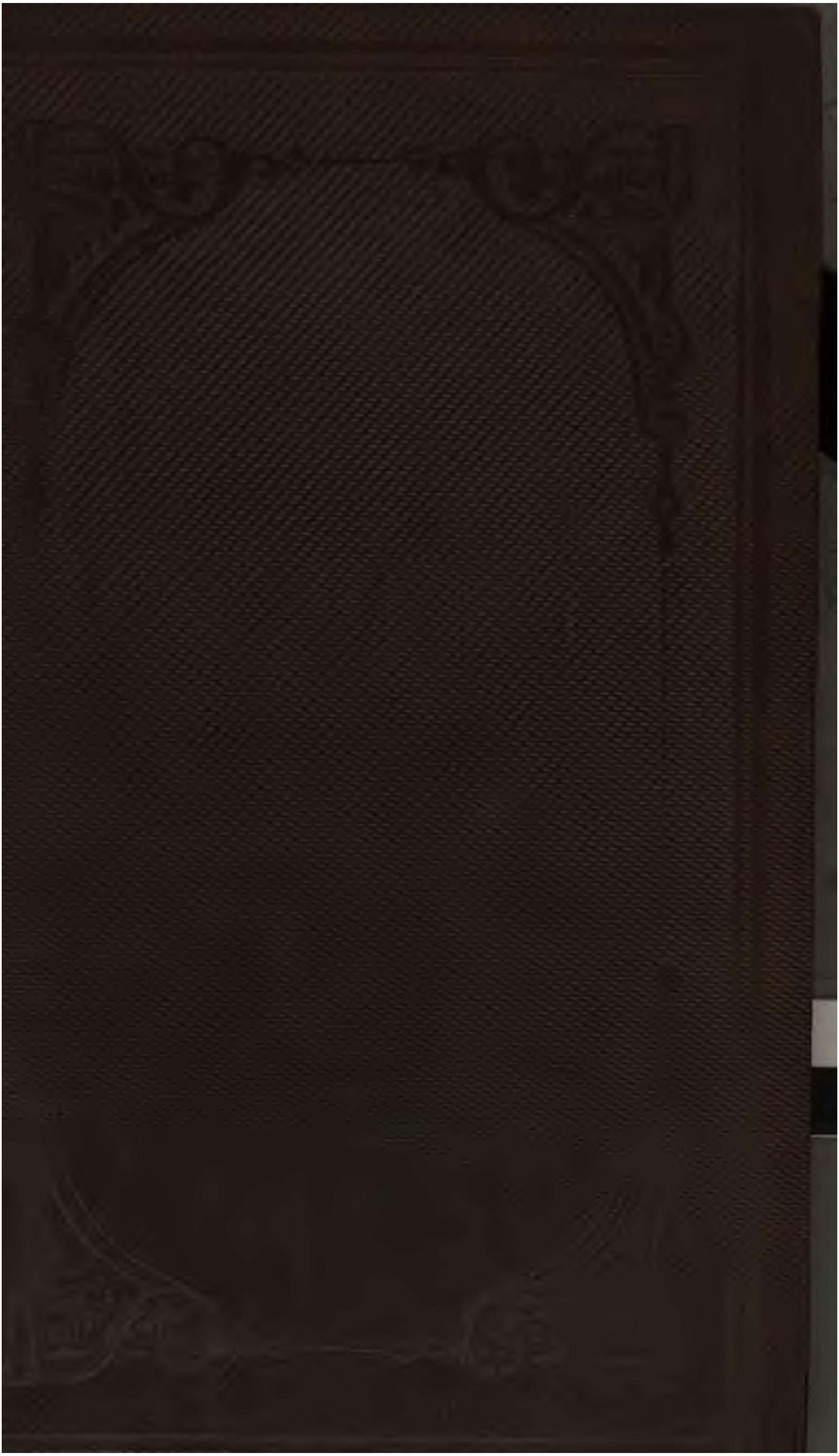
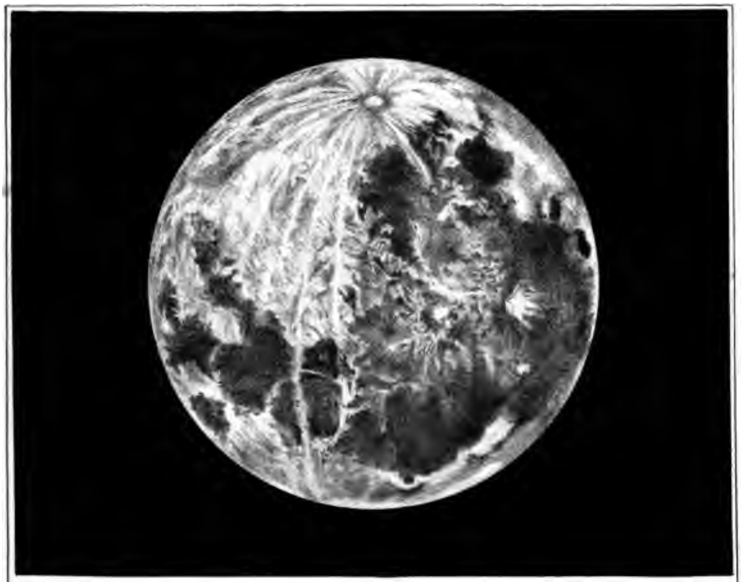
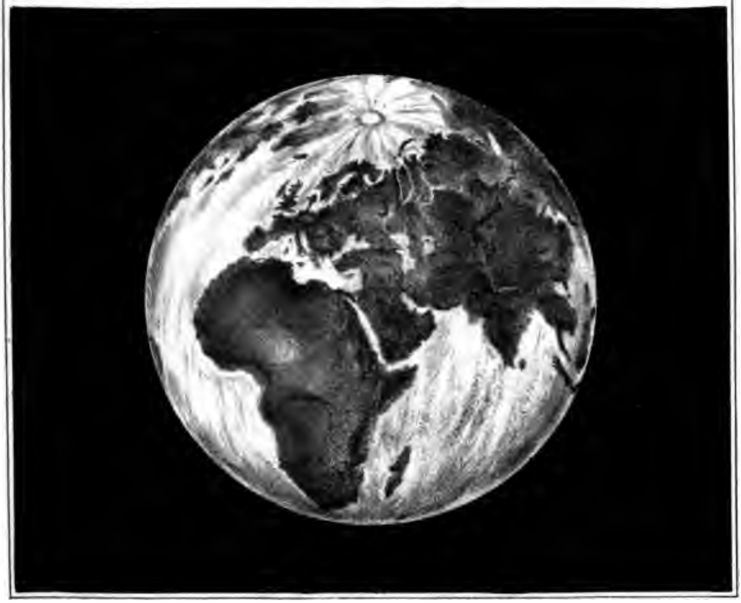


THE MOON, AS SEEN FROM THE SOUTHERN HEMISPHERE.
SHEWING HER VISIBLE NORTH POLE.





E.H. del

Vincent Brooks lith

THE EARTH, REDUCED TO THE SIZE OF THE MOON,
WITH ITS NORTH POLE TOWARDS THE SUN.

GEOLOGY

AND

TERRESTRIAL MAGNETISM:

BY

EVAN HOPKINS, C.E., F.G.S.

> "We freely confess that we are entirely unacquainted with the laws of terrestrial magnetism; and if any philosopher be so fortunate as to bring these laws to one principle, it will no doubt be one of the greatest discoveries ever made."—BIOT.

THIRD EDITION,

WITH A NEW AND ILLUSTRATED INTRODUCTION AND APPENDIX, TWENTY-NINE PLATES, AND NUMEROUS WOODCUTS.

LONDON:
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ALERE FLAMMAM.

OTHECA·BODLEIAN

PREFACE.

THE First Edition of this Work was written in South America, during the years 1837 and 1838, and published in 1843. At that period the *igneous theory* prevailed, and was made to account (but in a very extraordinary and impossible manner) for the formation of the fundamental crystalline rocks, mineral veins, and various other geological phenomena.

Although the Author's theory of the *electro-magnetic wet process* was at once accepted by miners and other practical men engaged in mining and quarrying, as being most *in accordance with the observed facts*, yet theoretical geologists in general opposed it, and maintained the inconsistent and worthless igneous creed, against the evidence of direct observations and experiments.

Since that time geological views have undergone many changes, and the igneous theory has gradually, but slowly, given way to the natural and more rational idea of the *wet process*.

It is true that some of the leading geologists who formerly maintained and propagated the igneous doctrine, and published works thereon, may still cling to their old favourite creed; but the overwhelming accumulation of facts which are daily being brought forward, must sooner or later free the science entirely from such a monstrous theory. In 1851 a Second Edition of this Work was published, in which the electro-magnetic wet process was further corroborated by more extensive observations by the Author in America and Europe, and the laws of metalliferous deposits were made still more apparent, and rendered also applicable to the guidance of miners in their subterranean explorations, both in the crystalline and sedimentary rocks.

Since the date of the last edition, MM. Daubrée and Bischoff have made observations on hydrothermal action, or the influence of *water* in the formation of rocks, and have thus led geologists to reconsider the subject, and to give due weight to arguments which they had so long opposed.

This electro-magnetic wet process of crystallization &c. must not be confounded with the old crude *mechanical* theory, called the "Aqueous," introduced by Werner. It is as different from that as the formation of a *crystal* is from that of a *sediment.* The one operates by *attraction and chemical action,* and the other by merely *mechanical deposition.* The former action produces the crystalline rocks, and the latter the sedimentary beds.

Professor Ramsay was at one time a most determined opponent of the Author's theory; and it is therefore but justice to that gentleman to state that he was one of the first to acknowledge the value of the Author's observations on the wet process when it began to be entertained by foreign savans. Professor Ramsay, when President of the Geological Society in 1862, in complimenting MM. Daubrée and Bischoff on the result of their investigations, observed that "he could not pass over the papers and works of one of their own members (Mr. Hopkins) on this very same subject, which he had brought before them, and had strongly maintained *for many years before the investigations now referred to were undertaken.*"

Sir Charles Lyell, in his address at the Bath Meeting of the British Association, remarked, "the study, of late years, of the constituent parts of granite has led to the conclusion that their consolidation has taken place at temperatures *far below those formerly supposed to be indispensable.* . . . . Various experiments have led to the conclusion that the minerals which enter most largely into the composition of the metamorphic rocks *have not been formed by crystallizing from a state of fusion,* but that they have been derived from liquid solutions, or in *the wet way.*" . . . . Adding that "the exact nature of the chemical changes which hydrothermal action may effect in the earth's interior will long remain obscure to us, because the regions where they take place are inaccessible to man."

Although Sir Charles Lyell omitted to notice the writer who first put forward these views, and who had laboured for so many years in these investigations, yet it is some satisfaction to find that he at last admits the value of the hypothesis, and that it is now also adopted by *foreign* geologists.

It was shown in the First Edition of this work that the silicification of fossils did not require igneous action, that it was a slow wet process, having no other origin than in those chemical operations which are constantly going on, and that their greater or less intensity in certain favourable localities produced siliceous fossils; even the stumps of trees become silicified during their growth. (See page 39.) A kind of chemical transposition appears to take place between the silica and the organic tissues, &c. This *wet* siliceous process is at length recognized by many naturalists as the *modus operandi* of what we may call the subterranean laboratory, instead of the imaginary *igneous* process, formerly entertained.

The President of the Geological Society, in his anniversary address in February last, remarked on the changes of geological views.—" Recent investigations have upset the ancient theories, that all the highest points consisted of crystalline rocks, and that no sedimentary rocks formed high mountains. Again, it was formerly supposed that the crystalline rocks, particularly granite, owed their origin to igneous action. Now it is well known that these granites are chiefly arranged in layers. The granite passes into gneiss, and the gneiss into mica-schist and talc-schist, and this is again closely connected with the green and grey slates; and it is well known that many of these rocks, formerly considered as plutonic, are really metamorphosed rocks"*.

Hence it will be observed that geologists now appreciate and adopt the views of the Author as to the character of crystalline rocks, explained in pages 45, 46, and 47 of this work.

The President, Mr. Hamilton, also remarked with reference to another change in geological ideas, that "We are daily becoming more convinced that no real natural breaks exist between the Faunas and the Floras of what we are accustomed to call geological periods. . . . . . We learn now that those forms of animal life which roamed over the surface of the earth before man came to *exercise* dominion over them, were not, as was at one time supposed, destroyed before his arrival, but continued to coexist with him, until the time came when they were to make way for other forms, more suited to the new conditions of life and to his requirements."

Professor Ansted, in his 'Geological Gossip,' makes the following observations on the changes in the geological creeds:—"An account of the correction of mistakes in geology might furnish matter for many very amusing and instructive chapters in a Work like the present. Few of the younger geologists of the day, and fewer still among general readers, have any idea of the extent to which opinions have become imperceptibly modified in many important departments of geological science within the last quarter of a century, while there have not been wanting several absolute and formal recantations enforced from time to time by direct discovery. The great cause of this is to be found in the inveterate habit that almost all of us have of over-estimating the value of negative evidence.

---

* The primary crystalline rocks are formed in parallel vertical bands, not stratified, but divided in plates like crystals. See the section of the Andes, Plate 7. The distinction that exists between the semicrystalline vertical *bands* of the primary series, and the *stratified* sedimentary rocks, is not yet fully recognized.

"Geologists examine a certain district, and remark the absence of some objects or group concerning which there seems no good reason why it should not have been handed down as perfectly as some others that have been preserved. At once the theorist jumps to the conclusion that the tribe of animals not represented had not yet been created. A theory is soon built up on the strength of it; for no one can oppose it without having the *onus probandi* thrown upon him. But some fine day the required fact is discovered, often to the disgust of the theorists—to the equal vexation of the student, and it would almost seem to the annoyance of everybody.

"The first impulse of human nature is to put the unlucky discovery on one side—say nothing about it

—most likely it will bear investigation, and therefore don't let us have the trouble of investigating it. It is so painful to be stopped in a pleasant career of progress, and to be obliged to examine carefully, and weigh fairly, the evidence in regard to a matter we thought settled when we began work some twenty years ago.

"A troublesome Frenchman—M. Boucher de Perthes, —took it into his head that some remains of men ought to be found in gravel. M. de Perthes, although he found plenty of specimens, and published an octavo volume about them, and even offered his specimens to the savans of Paris, could not obtain a hearing. Few readers, either in France or England, seem even to have been aware of his book. The subject was tabooed because people's minds were quite made up on the subject, confiding in the strength of the negative evidence, which really meant little more than a total absence of inquiry." 'Geology and Magnetism' was first published twenty-two years ago, and has been subject almost to a similar treatment from English geologists.

Since the date of the Second Edition, published in 1851, the Author has travelled over a very large portion of the Eastern Hemisphere, from Europe to Australia, and has examined carefully and surveyed large tracks of continents, islands, &c., especially the gold-regions of Australia. The result being that he was still further confirmed in his confidence in the principles herein enunciated.

The Author is fully conscious of numerous imperfections in the manner in which he has endeavoured to account for the various phenomena, in all their multifarious details; but he feels strong in his convictions as to the *general* truth of the *principles* he advocates, and of the connexion of all the great geological mutations upon the globe with the operations of terrestrial magnetism.

15 Clarendon Gardens, Maida Hill,
London, W. October 1865.

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OPINIONS OF THE PRESS.

"The book contains very valuable information, somewhat closely connected with topics of great interest to this country..... It is quite beyond my ability to give a fair analysis of this book; and I will conclude what I have to say by recommending those who are practically acquainted with the mineral condition of the country to peruse the chapter relating to the filling of veins. It seems to me to throw out lights which might or might not fall in with their local experience; but which would at all events afford matter for profitable inquiry and comparisons," &c.—*Sir Charles Lemon, Bart., M.P., President of the Royal Geological Society of Cornwall, in his Annual Address,* 1844.

"In this case, nature accomplishes on a large scale what experimentalists achieve with the galvanic battery; and if we admit the existence of subterranean currents, and that these exert a slow decomposing power, like that of the battery, we have sufficient power for our purpose ..... In this way may be explained the formation of veins that have long puzzled the geologist. This places geology and magnetism in quite a new light, disclosing a field of labour that promises a brilliant harvest to the persevering investigator," &c.—*Chambers' Journal.*

"Hitherto geological science has been designated as a vague and useless doctrine by many of our practical miners; and it is true, that primary rocks, with their mineral veins, have been left by speculative geologists, as *terra incognita,* in complete obscurity; but we are happy to observe a change for the better; the science is beginning now to have a more useful and practical bearing, and men are getting more anxious to learn it; and it is to be hoped, that with this combined influence and the diligent accumulations of new facts, such a degree of certainty will be obtained, as may enable them to predicate with some confidence, not only questions connected with mineral deposits, but likewise all phænomena which it comprehends. We have been led to make these observations on this interesting subject, in consequence of Mr. Hopkins's new system of Geology, which, owing to its practical applications to mining, and the satisfactory manner in which it accounts for all phænomena connected with terrestrial physics, is becoming an established system with practical men. The interest has been considerably enhanced of late, owing to the recent discoveries made by the indefatigable Dr. Faraday, corroborating, in a remarkable degree, Mr. Hopkins's general views, as explained in his work."—*Mining Journal.*

"The igneous theory—the doctrine of central fire—has for some time been slowly yielding to other views. All the phænomena attributed to fire may be produced (according to Mr. Hopkins's system) by electro-magnetic currents. It is difficult to imagine the existence of fires unsupplied with the oxygen of the atmosphere . . . . Even the cause of the variation of the needle, mysterious as it has hitherto appeared to be, may be referred to the relative energies of the magnetic currents. The wasting away and degradation of the land, which have often been viewed with alarm, are now shown to be compensated for by a process tending to the renewal and perpetuation of the physical universe. We look forward to the labours of Professor Faraday, as destined to throw further light on this interesting branch of science, in which he has already done so much. According to Sir John Herschel, we are to look to electro-dynamics for the *vera causa* of the Newtonian philosophy."—*Chambers' Journal, August* 1847.

"It is the best, and indeed the only principle hitherto propounded, which is capable of accounting for the various and complicated phænomena of geology, in a clear and satisfactory manner, in this, as well as in all other parts of the world, with which I am acquainted."—*Extract from a letter received from a geologist in Peru.*

"It is an acknowledged fact by all miners that the geology commonly taught is of no avail to them, and even the character of the primary rocks and the mineral veins is so imperfectly described, as to mislead those who study them from the ordinary books and lectures on geology. It is admitted also, that the only practical system of geology applied to mining, and now used by mining engineers, is 'Hopkins's Geology and Magnetism.'"—*Mining Gazette.*

SECOND EDITION.

"We strongly recommend a complete study of this work from beginning to end, so that not only the connexion of all its parts may be clearly understood, but to bring conviction to the mind of its demonstrative truths."—*Atlas.*

"Totally at variance with all the absurd dogmas of the igneous theory . . . presenting a true philosophical principle of terrestrial operations in every part of the world. How admirable are its explanations in metalliferous deposits and the gold fields of these colonies!"—*Colonial Press.*

"This is the most extraordinary work on record, and is truly the only work hitherto published on Geology which gives us a rational explanation of the changes we see going on in this world . . . . . . *Geology and Magnetism* will be appreciated, when many other works, now held in high repute, will be forgotten . . . . . It is a lasting monument of high acquirements, and must command the respect and attention of every one who is capable of appreciating its value, and feel an interest in the laws of terrestrial physics."—*American Paper.*

INTRODUCTION.

It will be admitted by all philosophers, who are labouring more for the cause of truth than for that of upholding human doctrines, that the conclusions of Geology, like those of every other inductive science, should be grounded on the *sole* authority of well-ascertained and classified facts, properly established; and that we should be guided to such facts, neither by random conjectures, nor by the dictation of authoritative opinions, but by the *sole* pursuit of natural analogies, and unquestionable data founded on direct observations in all parts of the world.

Were we to proceed on such philosophical principles, we should soon see that the science of geology is not such a crude, incongruous, confused compound of elements, as many now suppose it to be. On the contrary, we should find it most beautiful and harmonious in its design, order and arrangement, wonderful in its productive results, and, in a word, most sublime in the general œconomy of nature. It is man—owing to the short period of his existence—his very circumscribed sphere of action, the fertility of his imagination, and his not being able to place himself at a distance whence he could view the whole operations of nature and comprehend the grand scheme of the creation—who describes this globe of ours as an accidental and artificial product—hot or cold, hollow or solid—a wreck of worlds, or a chaos of melted matter, according to the immediate object of his thoughts and inquiries.

Violent incandescent eruptions are often assumed to account for physical changes, which may be observed as daily taking place in different parts of the world, by means of the ordinary slow and imperceptible process of nature. Our globe, according to the notions of many persons, has been brought to its present state of mineral structure and configuration, by repeated melting, roasting, boiling, freezing and scratching, as fancy or fashion may lead the way. These theories, however, do not, generally speaking, proceed from men who have been thoroughly trained in the laws of terrestrial physics and practical science, nor from persons who have examined and studied the phænomena of existing volcanoes, their effects, glacial movements, and the laws of metalliferous changes, as seen in various parts of the world; on the contrary, they often proceed from geological aspirants, who have never seen any other rocks than those in the immediate vicinity of their local habitations, which may not equal a spot that could be covered by the point of a finger on a globe of six feet in diameter, nor yet a depth equal to the thickness of its varnish coating.

Unfortunately it frequently happens, that the more limited the experience and scene of observation, the greater the presumption and consequent injury done to the progress of the science of Geology; we need not therefore be surprised at the extravagances and inconsistences of many of the theories advanced.

The science of Geology is comparatively of very recent date, and is pre-eminently one of direct observation, requiring careful and extensive analysis, mineralogically, chemically and mechanically, in connexion with natural history. Besides, these examinations must not be confined to any given district or region, but should be extended over the entire surface of the globe before the question can be justly comprehended.

The want of these essential elements for the investigation, the tendency of the human mind to draw conclusions from isolated and exceptional phænomena, confined to limited districts, and the assumed fanciful hypotheses which are so often substituted for facts, are the causes of the difficulties attending the progress of the geological science, and of its being unavailable for useful purposes, and held in such low estimation amongst practical men. Let us turn over a new leaf, and read the book of Nature as we see it, neither adding to, nor taking from it the meaning of its true context; and let us endeavour to interpret each page as we progress, or in other words, let us act as if we were strangers coming from the realms of space to examine this globe, to make a systematic survey of its contents, movements and changes, and to give a faithful account of the whole, irrespective of the theories of its inhabitants. This is the only way to act if we intend to proceed in our labours in the true spirit of philosophy. We must revise our theory of terrestrial physics, to render it worthy of our esteem; and make it *equal* to the present advanced state of practical science and its branches as applied to human industry.

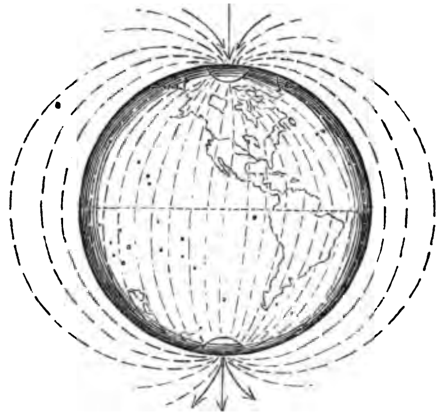
On entering into the subject of our inquiry, we must necessarily investigate the whole of the terrestrial sphere as we now find it—with its aërial, aqueous and semiaqueous covering, permeated with that universal power which we call polarity or magnetism. We must then watch carefully their combined operations—the changes and sequence which actually belong to them, and follow their natural consequences.

Let us endeavour to keep ourselves strictly within the boundary of demonstration, taking nothing for granted, but confining our investigations to the existing laws of operations, and to the accumulated mass of unequivocal evidence lying before us, without in any way altering their characteristic conditions and effects.

In taking a general view of our globe, we find that it rotates on an axis, the two ends of which are called the South and North poles, and that it is not only enveloped

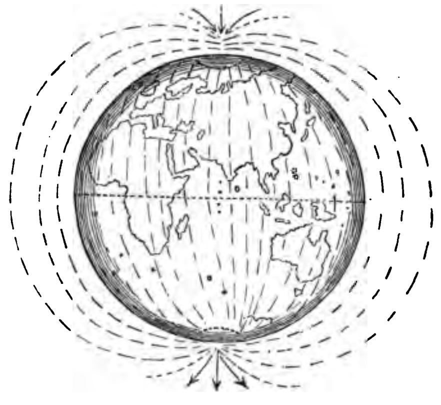
Western Hemisphere.

Fig. 1.



Eastern Hemisphere.

Fig. 2.



in an atmosphere, but also enclosed in an invisible and subtile power, which we find universally present, and which is incapable of being removed by human means. The existence of this power is ordinarily known by the indications of the magnetic needles, forming what are commonly called magnetic meridians, which converge at the respective poles, as described in figures 1 and 2.

All mariners who have traversed the ocean from the Antarctic to the Arctic regions, are necessarily familiar with the fact, that the south ends of the magnetic needles drop, and if suspended tend to become vertical, as they approximate to the South pole, and as they recede, the needles, with some slight local variations, are retained and preserved, more or less, in the meridian, until they approach the North pole, when the north ends begin to drop, and if suspended, will become vertical when in close proximity to the pole.

These facts are so well known as not to require further comment in these preliminary observations.

They have been further proved experimentally, showing that such is the linear direction and general character of the curves from pole to pole on a globe under the influence of that power called Magnetism. These meridional lines of active forces, traced from pole to pole, are not confined to the ocean, but are also detected all over the dry land, in the air above, in the waters below, and in the deepest recesses of the earth beneath; and this important fact is capable at all times of being put to the test in every part of the world, and therefore beyond the power of contradiction.

The next striking and general fact we detect is, the tendency of the crystals, that compose what we denominate primary rocks, to form in a linear direction, and in compounds of crystalline plates, more or less, in a vertical position, with a similar meridional disposition as the magnetic needles, thus indicating a connecting cause. The diagrams annexed will, at a glance, show the general character of the structure of the primary rocks, as observed in all parts of the world, when carefully examined on a large scale, and in deep sections.

Fig. 3.

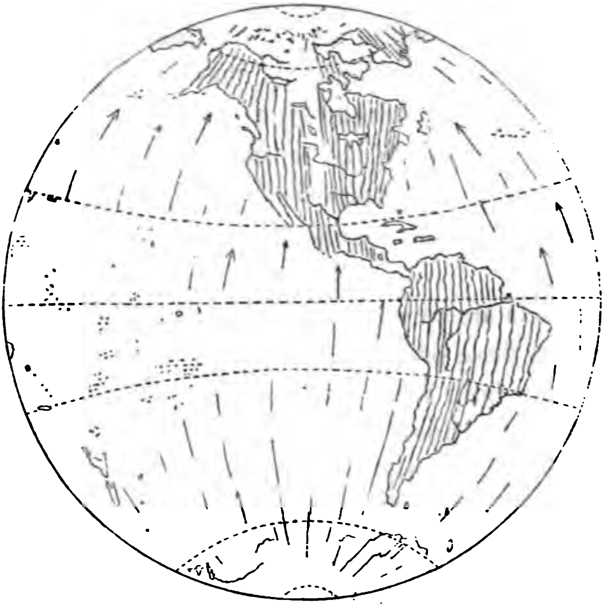


Fig. 3 exhibits the meridional structure of the primary rocks (granite, gneiss and schist) of the Western Hemisphere, from Terra del Fuego to the northern regions. Fig. 4 shows the same kind of structure from Van Diemen's Land, Australia, Africa, India, China to Siberia and Norway. Fig. 5 is an equatorial section, exhibiting the vertical or rather (with reference to the globe) the radial character of this meridional structure, called lamination, cleavage planes, foliation, &c., forming crystalline bands which are commonly mistaken by many geological writers for upraised sedimentary beds or tilted strata.

Fig. 4.

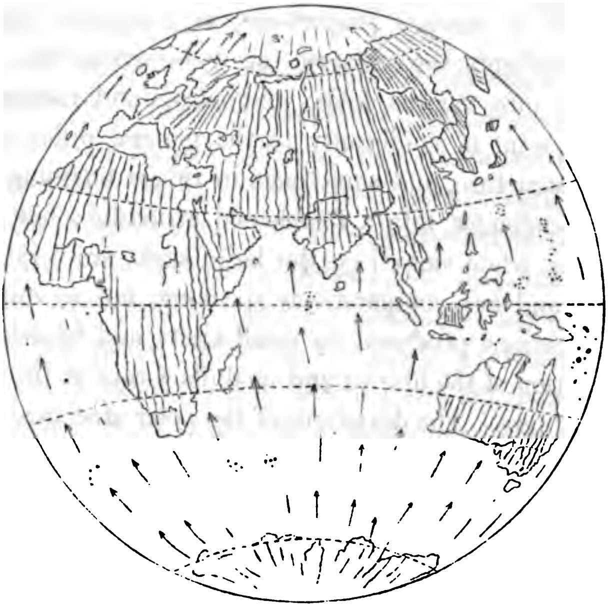
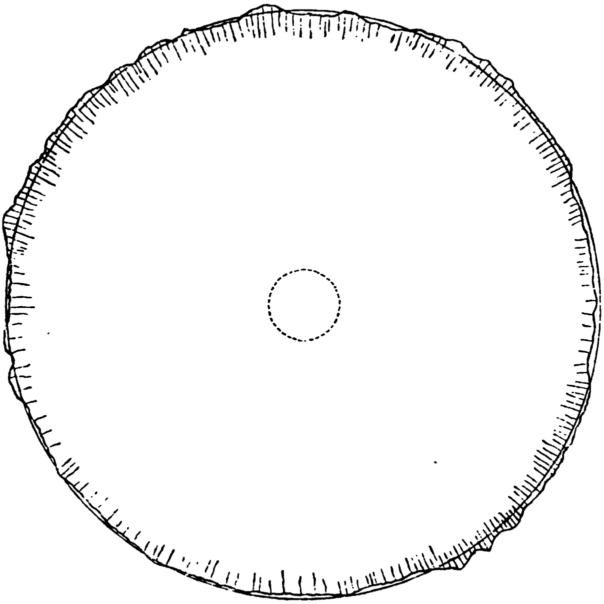


Fig. 5.



Locally, in districts where mica and talc happen to have aggregated in unusual proportions, as compared with the other ingredients, the schistose variety becomes often much contorted into various folds, undulating and causing an apparent want of conformity to the general order of the primary structure, and sometimes in ridges inclining from the perpendicular into a fan-shaped structure; but these deviations, when viewed on the large scale, are very insignificant, and are, comparatively speaking, not so much as the contortions produced by small knots and branches on the direction of the fibrous and medullary rays in the trunk of a large tree. The deviations of the polar structure of the primary rocks, when viewed as a whole, are not so much as the variations in the direction of the magnetic force indicated by the needles, and yet the latter appears remarkably uniform, when we consider the presence of so many disturbing causes, and is found quite sufficient to guide our track in the darkest night in the middle of the ocean. We find that the greatest discordance, both in the direction of the magnetic needles and in the polarity of the structure of the primary rocks, exists in the northern region. From the south to the north temperate region, the respective polar phænomena are remarkably uniform, as will be seen on reference to the above diagrams, and the following notes.

Australia.—The phænomenon of the polarity of the primary structure is so striking in this part of the world, that the most superficial observer cannot help noticing it.

Whenever the crystalline rocks, slates, &c. are found uncovered and exposed to view, they are found *on edge—bearing north and south,* and continuing in that direction to an indefinite extent, without any deviation for many hundreds of miles, until hidden by layers of loam, sand and gravel.

In Mr. W. Howitt's recent work on Victoria, p. 71, vol. ii. he observes, "As I have said, these quartz ridges form portions of those singular ridges of rock which run from north to south over the hills of the gold regions here. A great portion of these ridges consists of clay-slate, or ferruginous sandstone, the strata (bands) being all perpendicular. It would seem as though some subterranean force, acting in this direction, had burst up the strata (crystalline bands) in these long north and south lines, and left them standing edgeways. They have a most singular appearance in the rocky woods, crossing the summits of the hills, and extending down the slopes, but disappearing in the valleys, being there buried by the alluvial soil. In the creeks, where the bare rock appears, you again perceive these ridges. They are always true to this one direction, and are nearly as good as a compass where they prevail; and you may trace them for twenty or thirty miles at a stretch, and, no doubt, they extend right across the Colony."

In the Proceedings of the Royal Society of Van Diemen's Land, vol. i. part 1, we find it stated that "Everywhere the bands of clay-slate are discovered in the same vertical position, and everywhere they have the same meridional direction..... Long Point is formed of massive granite, with clay-slate in vertical and meridional direction." In South Australia, "The mountain chains are composed principally of gneiss, mica-slate, chlorite-slate, and clay-slate enclosing quartz veins, and all on edge, running north and south, partially covered by sandstone and gravel." In the official reports on the Gold Regions of New South Wales, the same kind of polar structure is noticed:—"A large range of granite runs north and south in various bands, with boulders loosely scattered on the surface, in the plains of Bathurst. Further westward, towards the gold-bearing rocks, the formation changes into a series of white quartz and mica-slate, to Summer Hill Creek; thence argillaceous, chloritic, and hornblendic slates, to Canobolas range—all without exception in a vertical and meridional direction, and these extend from north to south throughout the colony." To be brief, it might be stated that this vertical and meridional structure of the primary series has been traced from the Australian Alps on the east, across the Colony of Victoria, Mount Alexander, the Pyrenees, and the Grampians; thence to South Australia, to Swan River on the west coast in Western Australia, and as far inward as travellers have been able to penetrate into the sandy desert. On the northern coast the same structure is seen continuing from New South Wales to Cape York in Torres Strait, and also in various parts in the slaty portions of New Zealand. This meridional structure is seen intersecting Java, Sumatra, the islands of Banca, Borneo, and the Philippine Isles. It has been examined and partially traced from Singapore, along the Malay Peninsula as far north as Thibet, as a vertical meridional compound of granite, gneiss, quartz, micaceous and ferruginous slate*.

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* "In the Malay Peninsula the bands of crystalline rocks are in general vertical, bearing sometimes to the west and at others to the east of north; but the average strike is about north and south magnetic. These bands of rocks run like walls amongst the trees and jungle, and may be seen in many parts of the coast in rows of ledges stretching into the sea, and thus forming numerous reefs, on which corals grow in profusion. Some of the vertical crystalline bands standing amidst the low trees and shrubs appear like the walls of ruins, some being only about a foot in thickness, while they rise to the height of 20 to 30 feet. Quartz bands are numerous. Many of the micaceous and

It has been carefully examined also in the island of Ceylon, and observed over a large area on the western side of Hindostan and in parts along the Himalaya Mountains. Sir Roderick Murchison, Baron Humboldt and others, have noticed the same kind of meridional structure along the chain of the Ural Mountains, and part of Siberia.

The meridional structure of the crystalline series prevails in South Africa, and in the interior as far as it has been explored in the south, and along the banks of the rivers on the west. We trace it also in Abyssinia, Nubia, and near Suez; on the north coast of Africa; in a word, wherever the primary series is left bare, and uncovered by the sedimentary deposits, the vertical structure is observed.

Europe is so much covered by sedimentary rocks as not to allow the primary rocks to be examined, except in very few places, and even many of these are found so much disturbed by subterranean forces, as not to present the same polar order of structure as in the regions above specified; hence the cause of the phænomenon not being understood or appreciated by European geologists. However, notwithstanding these obstacles, we find areas of moderate extent of uncovered primary rocks in Sweden and Norway, retaining with a little bend their normal meridional structure.

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talcose slates often present on their worn surfaces a strong resemblance to decayed wood, and the small nodules of quartz look like knots. Indeed had it not been for the fact, that these rocks can be traced for some hundreds of miles north and south, they would be considered as fossil wood. This appearance arises from the fine lamination of the slates and the different colours, with the undulating seams of the mica, talc and chloride, giving all the appearance and varieties of grain which a large plank does. These bands vary in colour from chocolate to violet (but sometimes also bluish and greyish), the folia extremely fine, and a glistening lustre on their faces or cleavage planes. Wherever there is much quartz and talc the bands and laminæ are greatly deflected."—*Journal of the Indian Archipelago.*

Also (with a slight variation to the N.E.) the primary series may be traced from Ireland to the N.E. coast of Scotland. This structure is well developed in the Western Isles, where the gneiss and schist can be examined. A small range may be seen in Wicklow running north and south, and a few patches in Cornwall, Wales, and the slaty districts of the North of England, having a bearing to the N.E.*.

Portugal and Spain show the character of the structure of the gneiss, over a very extensive area; we find it also in France from the Gulf of Lyons to the English Channel; in Germany the same kind of structure may be seen in various places, more especially from Vienna to Berlin.

In *the Western Hemisphere* the meridional structure is first seen in Terra del Fuego, then throughout Chili, Patagonia, the Brazils and New Granada; also across the three branches of the Cordilleras, as shown in Plate VII.

The following sections from East to West will serve to give a general idea of many parts of the primary series of South and North America, transversely, partially covered by sedimentary rocks:—

Section from East to West.—Fig. 6.

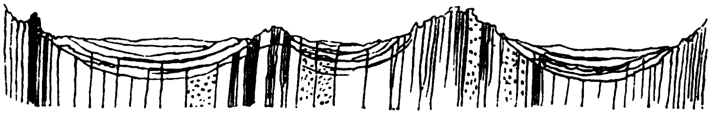


Fig. 7.

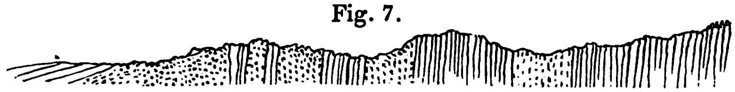
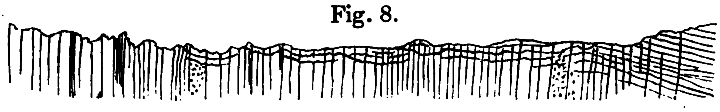


Fig. 8.



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* As the slaty cleavage of the old sedimentary rocks has been induced by the primary structure underneath, it serves the purpose of tracing its direction, although covered by such deposits.

Fig. 9.

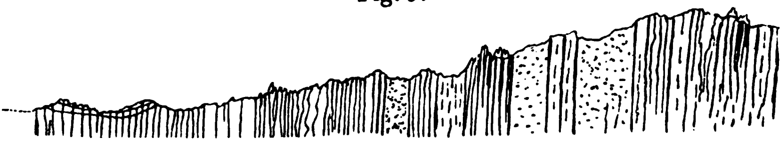
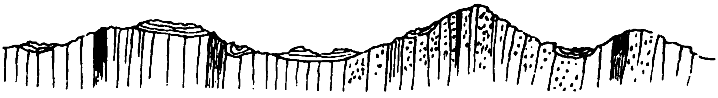


Fig. 10.



It would be an endless task to describe the various localities, as they all present the same character. In Veraguas and Central America, from Mexico to Sierra Nevada in California, the meridional and more or less vertical structure prevails, as will be seen on reference to the geological description of the respective countries.

To the East and bordering the Appalachian Chain, from the states of Georgia and Carolina, to Canada and Nova Scotia, although somewhat bent into a north-easterly direction like the crystalline rocks in Europe, the order of the primary structure is sufficiently uniform to display its prevailing character, and to show the magnitude and universality of the polar phænomenon.

Currents of the Ocean.

We shall next proceed to notice another general phænomenon which has some reference to the poles; it has been somewhat neglected by scientific men, although well known to mariners;—we refer to the great movements of the oceanic currents from south to north.

To those who have not been much on the ocean, and who are not accustomed to nautical language, the expressions of "going up" or "going down" in the middle of the sea would sound strange. For instance, captains on the Atlantic and Pacific oceans say that they are "going up" to the Capes Hope and Horn,—Australia, &c., or "down" to New York, England, California, &c.; these sound something like arbitrary terms, yet they are strictly correct; they are expressions in accordance with the direction in which the currents of the ocean flow, viz. up against the stream and down with it. The general currents of the ocean are as familiar to mariners, as the Gulf-stream is to the Americans. Whatever drops on the ocean in the southern zone, if not checked in its course, and if preserved floating, will finally be carried to the northern regions.

The west coast of Ireland and the north polar regions present many examples of this great movement of the ocean. It is true we have no such meridional linear order in the saline liquid as that just described in the rocks and magnetic needles, yet the path of the streams may be traced along the configuration of the great continents and islands from the south to the north. These streams are propelled by impulses of periodical waves, which may be called the tidal waves, from the south polar region. They first come, expanding as a ring, from the south polar basin, and move in the same parallels of latitude, until they strike against Van Diemen's Land and Terra del Fuego (two opposite places), nearly at the same time; then they become divided, and diverged from their normal, circular, and latitudinal course by the configuration of the islands and continents.

This undulating stream impinges on Cape Horn and becomes divided. The current sets northward on the coast of Patagonia;—a bottle thrown into the sea off the Cape in 1837 was picked up on the coast of Ireland. The Chilian branch, after coasting Peru, becomes bent to the north-west, owing to the shape of the coast, and is considerably dammed, thus causing a much greater tide, and a kind of circular movement between the Gulf of Panama and the Galapagos Islands*.

From this place it proceeds in a north-westerly direction towards the Sandwich Islands, and there meets the stream coming from the Chinese Sea, or the Japanese current on its way to the north. In the Pacific, the tidal wave is not so much interrupted in its course as in the Atlantic; hence this ocean is much more calm, and subject to less tidal oscillation than the Atlantic and Indian Oceans. At Campbell Island, to the south of New Zealand, the current frequently runs at the rate of about ten miles per hour, the same as along the west coast of South America; but the great expanse of the ocean at the equator diminishes the velocity, and owing to the various changes in the direction as above explained, a large neutral space is formed embracing the Polynesian Islands, where scarcely any stream is detected, and where a small tidal wave is seen only every twenty-four hours. [See New Ireland.]

Hence this is the region of calms—the sea of high temperature, wherein islands and sand banks are formed, and on which the corals grow in luxuriant clusters to great magnitude. The nautilus and various mollusca still abound here, the fossils of which are detected in sedimentary deposits in the northern regions. The islands in the Bay of Panama present also similar products, but on a smaller scale.

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* The steamers running between Chili and Panama are obliged to have their coppers cleaned at the Island of Tobago, where the tide varies from 18 to 24 feet, in consequence of there not being sufficient tide at places further south to do so. The tides in Chili and New Zealand do not exceed 4 feet; in Auckland Island they are only 3 feet.

The tidal wave, as it strikes against the southern coast of Australia, proceeds in a north-westerly direction towards the Indian Ocean, leaving a small branch to separate and go between Van Diemen's Land and the colony of Victoria to the Pacific. The main stream, as it arrives in the Indian coast, causes high water on all sides almost at the same time. The tide at Van Diemen's Land, Australia and Ross Island, amounts only to 6 feet, but on being dammed against the coast of Bombay, it becomes much greater. The narrow Straits of Babelmandel and the protecting points of the east corner of Africa check its inland rush, and thus cause in the Red Sea a tide of only 6 feet. From this coast the stream bends to the south-west and forms the Mozambique current, running between Madagascar and the African Coast to the Lagulhas Bank, where it turns back to the north and unites with another stream from the south. A large portion of the great stream of the Indian Ocean enters the passages between the East-India Islands, the Chinese Sea, &c., and then flows northwards, towards Japan and the polar regions.

These bends, &c., cause a great circular movement in the Indian Ocean, somewhat similar, although on a lesser scale, to that observed in the Pacific, causing calms, banks and islands, which, like Keeling or Ross Island, favour the growth of corals, and on which the cocoa-nut and palm-trees are seen flourishing most luxuriantly. Ross or Keeling Island is formed in the shape of a horse-shoe, by the growth of corals. The bed of the sea within is somewhat shallow and flat, showing distinctly that it is not a volcanic production, although the shape might make it appear that such was its origin*. The great Atlantic current or tidal wave, after bending round the Cape of Good Hope, proceeds along the western coast of Africa northward, at the rate of 10 miles per diem, causing tides of about 3 feet at St. Helena and Ascension Islands, until it comes in contact with the bend in the Gulf of Guinea, where it changes its course again to the north-west, and produces what are called the "Trades" of the Atlantic. One portion moves in the direction of the Bermudas; the other enters the Caribbean Sea along the Spanish main.

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* The coralline islands are generally famous for their springs of

The latter is deflected by the Isthmus of Panama and follows the sinuosities of the coast line to the Gulf of Mexico; it then returns back to the open ocean, after a rotatory movement at the latter point. It comes out here as a warm, rapid current, known to mariners as the *Gulf Stream,* and deflects from the Straits of Bahama, in a north-easterly direction, towards Newfoundland and Norway. Before this warm current reaches the Azores, it separates into two branches, one towards Ireland and Norway, while the other flows in the direction of the Canary Isles and the western coast of northern Africa, thus forming a great oblong rotatory mass of water (similar to that described in the Pacific), and producing a great field of sea-weed.

The Atlantic current, in consequence of passing through such a long undulating path in the tropical zone, and being further heated in the Gulf of Mexico, carries very warm sea to the north-west of Europe, thus rendering the temperature much higher than is due to the latitudes.

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fresh and cold water, in the middle of the ocean in the torrid zone, and present a very strong evidence of their having been formed by the action of submarine springs, forcing up mineral matter and forming cones like those of volcanoes. I have carefully examined them in the Pacific and Indian Oceans.

Part of the wrecks on the coast of St. Domingo have been found (carried by this stream) on the north coast of Scotland. Also casks with palm oil from wrecks off Cape Lopez in Africa have in like manner been conveyed to the north of Scotland. The winter cold of the most northern part of Scandinavia is ameliorated by the action of the Gulf Stream (running towards the north polar basin), which carries American tropical fruits, cocoa-nuts, &c., beyond 62° N. lat.; so also Iceland enjoys, from time to time, the genial influence of the diffusion of the warm waters of the Gulf Stream, far to the northward. Very slight alterations in the configuration of Africa, the Isthmus of the Darien, and Florida would cause great changes in the climate of Europe. The sea coasts of Iceland, like those of the Faroe Islands, receive a large number of trunks of trees and fruits from the tropics, periodically presenting unequivocal indications that the movement of the ocean is from the south. A very large quantity of sea-weed is seen constantly floating between the Bermudas and the Azores, within the limits of the neutral mass of water alluded to above; and corals also are seen fringing some of the Bermuda Islands. Some of the weeds, by the circular movement of this part of the North Atlantic, are carried back to the north-west coast of Africa, where the action is repelled again by the normal southern current.

The tides in the Caribbean Sea only amount to about 20 inches. They increase on the east coast of North America, and when the current comes in contact with Nova Scotia, and enters the Bay of Fundy, the tidal wave—in consequence of the damming effect of the land—oscillates to about 70 feet; whilst on the north side in the gulf of the St. Lawrence it scarcely amounts to 6 feet. The oblique north-easterly current, on arriving at the British Isles, is exposed to similar effects; thus producing high tides in the British Channel and a circular movement round the North of Scotland to the German Ocean, until it meets a branch at Dover coming from the British Channel.

Inland seas are not exposed to the action of these oceanic currents; consequently they have no tides. Neither is there much effect produced on such seas as the Mediterranean and the Baltic, because their narrow straits are to the west and north, and not to the south. Inland seas, which are open to the south, are subject to the oscillations of the oceanic tides.

This will show how very inapplicable is the common theory of the tides to the actual movements of the ocean, and how very incorrect the knowledge of the tides must have been when such a theory was first propounded and accepted.

Diagrams Nos. 11 & 12 will show, at a glance, the general direction of the stream from south to north. It is very important that we should have a more correct knowledge of the currents and the tides than we have had, and some idea of the laws that govern them. Indeed, it is by the increase of knowledge on these important subjects, which has been acquired by mariners, and which are recorded in the practical sailing books, that circular sailing has been of late years so much followed, and such quick passages made to and from the Antipodes. The records of observations are our only guides in all these questions, and not the theories which have been propounded.

The ocean and its currents have been and still are important active geological agents in forming and modifying the configuration of the islands and continents, and in spreading the local deposits of great rivers over large areas.

Fig. 11.

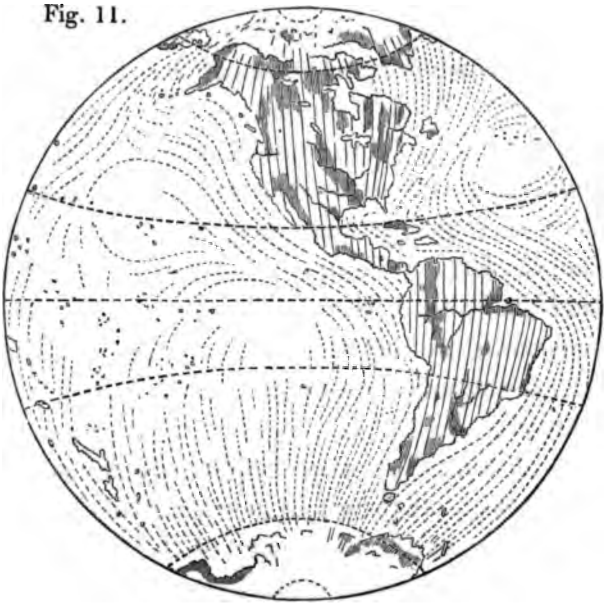
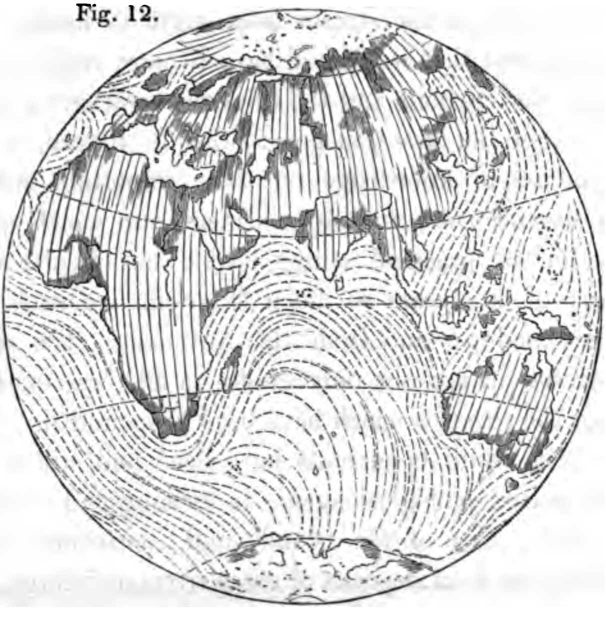


Fig. 12.



Shoals are increasing and diminishing according to the variable character of local conditions: even a slight alteration in the bend of a continent, or a break in an isthmus, would cause a very great difference in the temperature (such as Europe for instance), and thus change the nature of the deposits and render many parts unfit for the majority of the existing plants and animals within the limits of certain regions; under such circumstances they would have to retrograde south, to a more genial clime, or dwindle and perish like their predecessors.

Having now glanced over the main features of the globe, and the great operations that are perpetually at work, we shall proceed to investigate the consequent results in the same manner, and trace their general connection.

Sedimentary Deposits.

We shall now enter into questions more immediately connected with geological researches, in which there is so much discordance, and almost insurmountable difficulties, in reducing the valuable discoveries of the ancient organic productions into one consistent system.

The frequent new discoveries of organic remains, and the subdivision of sedimentary beds into distinct eras of long periods of time, &c., instead of advancing our science, appear to retard it, causing continual changes of a retrograding nature, and leaving the surrounding horizon darker than ever. Most important facts are constantly opposed, sometimes for many years, simply because they happen to be contrary to the doctrines which might be in fashion. Thus our Earth may become actually girded by the practical application of the law of Magnetism;—natural Chemistry may be applied in our manufactories—to the enrichment of the soil and nourishment of plants, to improve the soil and our agricultural industry—and our minerals may be discovered and converted into new purposes of life; our ships remodelled, the course of our circumnavigation changed; in a word, the whole of our *industrial* science may proceed centuries in advance of the *theories* of science, which are pertinaciously kept behind instead of progressing and aiding us in the march of improvements and discoveries.

In commencing the geological inquiry of the sedimentary beds, we shall consider, first, *the universality of the different geological formations.* Amongst the various theories promulgated by geologists, none have given rise to greater discussions, and led to the idea of successive creations, more than the one which maintains that the entire surface of the globe has been covered by separate and consecutive concentric layers or envelopes, enclosing distinct and different orders of organic beings, which were considered to have existed at long intervals of time; and as these were supposed to have been destroyed and terminated, each covering in succession required a new creation.

The bad effects of this doctrine are felt even in the present advanced state of geology, inasmuch as many persons still believe that the earth is universally so covered, and that the sedimentary deposits and the order of the organic kingdom are precisely the same in the Southern Hemisphere as in the Northern.

The fact is, the only rocks which may be considered as universal are the crystalline, *i. e.* the granites and the schists, as already described. These are found everywhere on the face of the globe, and always exhibit the same general character.

As regards the sedimentary rocks, from the oldest to the most recent, they are only found very partially, and are

Fig. 13.

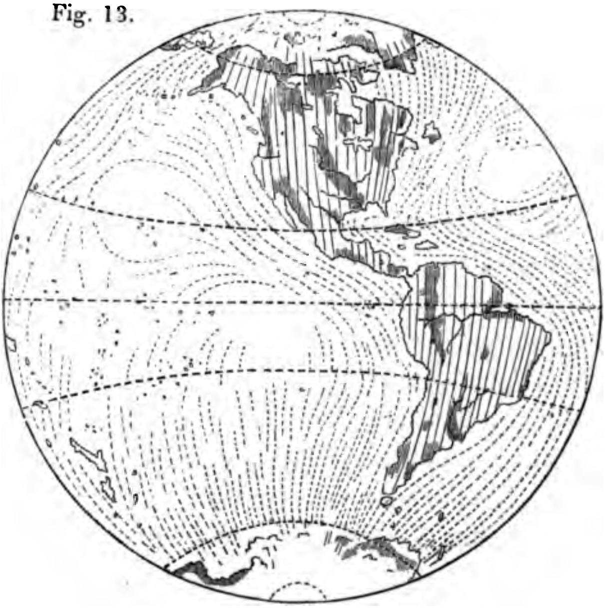


Fig. 14.

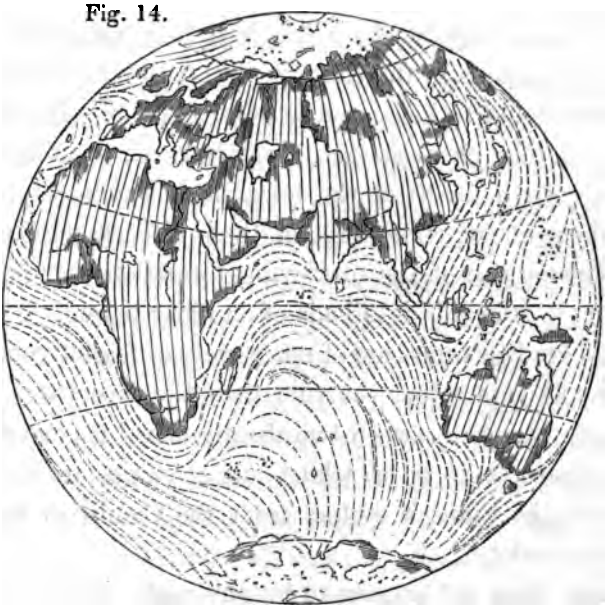


Fig. 13. The dark spots exhibit the sedimentary deposits of the Western Hemisphere, and fig. 14 the deposits of the Eastern Hemisphere.

necessarily extremely local, as shown in figures 13 and 14. A mere glance at a geologically coloured globe will show how insignificant is the extent of the area of the carboniferous formation, as compared to the entire surface; the same may be said of every division of the sedimentary series from the lowest to the highest. Yet these sedimentary rocks are so subdivided throughout into distinct groups by European geologists, as to make it appear that such was the normal and not the exceptional state of things in other parts of the world.

As our investigations have extended to distant regions of the earth, more especially to South America, Australia, Africa and India, new combinations of beds have been brought to light, showing the total absence of almost two-thirds of the grand series represented in the ordinary geological sections.

The limits and breaks which have been assigned to different formations in the countries where first observed have not been found to hold good in other regions. It has been observed that between these demarcations, as at first laid down, certain fossils of the lower beds extend higher up into those above, while some of those hitherto supposed to be characteristic of the overlaying formation are found extending downwards into beds of an older period.

This gradual transition of one variety of fossiliferous beds into another is rather the rule than the exception, and is a *vexata quæstio* between two distinguished geologists, and must continue to be so whilst any attempts are made to separate the Silurian system from the Cambrian by their organic contents.

There does not appear to be any probability of finding a definite line of separation, as a careful examination tends to prove that the whole formation belongs to one organic system, from the old red sandstone down to the primary rocks; and were such a line to be found, stratigraphically, it would only be of local importance, and not applicable to other parts of the world.

These minute subdivisions have already caused the waste of valuable time, and considerable injury to the progress of the science: it is to be hoped that the subject will be freed from such endless discussions on trivialities, and that it will receive more attention in its more comprehensive character instead of being so much confined to the somewhat useless creations of the sedimentary beds into so many distinct systems.

To proceed with our subject.—In pursuing our researches we do not find similar development of sedimentary rocks in each geographical zone. In the Northern Hemisphere it is true we recognise, both in Europe and America, an immense series of highly consolidated deposits characterized by organic remains of different climes—of the south temperate and tropics in succession,—but the sedimentary deposits of the Southern Hemisphere are neither so numerous nor compact, and their organic contents in general bear strong analogy to those now existing in that region, without a trace of organic remains belonging exclusively to the north.

Were this most important geological fact better known and attended to by geologists, they would be much more guarded in their generalizations, and in order to prepare the reader to form a correct opinion on the subject, and to remove at once the idea of the existence of the same kind of sedimentary rocks over all parts of the world, as those which we find in Europe or the Northern Hemisphere, we shall begin to describe them from the south; first, in the

South temperate; secondly, Torrid; thirdly, North temperate; and, finally, in the Arctic region.

THE SEDIMENTARY ROCKS OF THE SOUTH TEMPERATE ZONE.

The first thing that strikes the observer in travelling over the plains and sedimentary terraces of Patagonia and the extensive sandy desert of Australia, with its limited sedimentary beds on its south and eastern flanks, is, that these dry lands are of comparatively recent origin.

The majority of the lagoons contain brackish water; the marine shells which are found scattered over the surface, if not identical, are at least so like those now existing in the bordering sea, as to be considered the same by all ordinary observers. The great siliceous trees are also apparently identical with the existing conifera of this zone. Although the vegetation is so strong and luxuriant in this hemisphere, yet the new gravelly lands that emerge from the ocean require centuries before the vegetable world clothes the dreary scene, unless they are connected to a pre-existing continent. The lands in the South Frigid and Temperate zones change their aspects almost suddenly from the barren wastes of the Antarctic to the rich and gigantic foliage of the South temperate.

There is no intermediate organic or vegetable band analogous to that which we see in the north; the change is abrupt from the frigid to a semitropical aspect.

The sedimentary rocks of Australia within the confines of this zone are very limited, and are only found in a few small patches in South Australia, Victoria, Van Diemen's Land and New Zealand, but more extensively in New South Wales. In the latter portion of Australia, bordering its eastern flank in the neighbourhood of Sydney, we find the carboniferous formation with its sand and calcareous beds resting immediately on the edges of the primary crystalline rocks, and cropping out along the western side of the Blue Mountains. This coal formation may be seen from the Hunter River to Brisbane Waters. On reference to figures 13 and 14, it will be observed that the sedimentary deposits of the coast conform to the direction and bends of the ocean currents. Seams of coal have been also found on the southern shores in the colony of Victoria—in Western Port and Cape Otway. The same formation extends as far as Geelong and Portland, but with only very thin seams enclosed in sedimentary clay slate. This, like the New South Wales formation, is immediately in contact and resting on the edges of the crystalline rocks, having neither an intervening system of beds below, nor yet above: the whole appears as one group of deposits.

On referring to the entombed organic remains in the sedimentary beds, we find that the fern trees, cycadeæ, araucariæ, &c., are the characteristic fossil flora, and although attempts are frequently made to separate the species from those now flourishing in the same region, yet those who are unbiassed by any theory cannot distinguish the difference between the living specimens and the impressions in the beds.

It is not easy to determine the species of living plants of an unexplored region from imperfect fragments: how slight is the clue in many cases afforded by a leaf; and how hopeless is the task when the botanist has before him only the fragments of a stem! Yet such are the materials from which, in nine cases out of ten, the describer of fossil remains constructs his extinct and new species.

Let us turn to Patagonia and Chili. There we find the tops of the mountains covered with the shells of the neighbouring sea, and the fossils of some species of the araucaria, conifera, &c., which still flourish on the land. On traversing any of the sections in Patagonia, from the Rio Santa Cruz to the base of the Cordilleras, and again on the Rio Negro, we find the whole of the sedimentary series of recent origin, and irregularly covering, or deposited on, the edges of the primary slate and granites. The shells and corals of the lowest deposit are those which belong to the bordering sea. Although it is difficult to distinguish some of them from the species found in the Silurian rocks of Europe, yet they are littoral species of the neighbouring coast, and are frequently found scattered at various heights from 1300 feet downwards. The whole of this country, like Australia, indicates a comparatively recent and gradually slow elevation from the deep; such uniformity of terraces could not by any means be produced by convulsive movements. It will, therefore, be observed, that the sedimentary deposits of the South Temperate Zone are comparatively very limited and recent, and that their organic contents correspond, more or less, with the existing state of things within that zone; the slight variation being no more than that which must naturally arise from the changeable physical conditions of the different localities, and the variable currents of the ocean.

In New Zealand, as in Australia, the fossil remains of the extinct animals are associated with those of the existing genera; and the land is still inhabited by diminutive representative forms of the colossal beings which flourished there in early times. New Zealand, like Australia and Patagonia, has undergone physical changes by which the areas occupied by the ornithic ossiferous deposits, and the beds of shingle and loam have been elevated, and now form terraces from 50 to 100 feet above the sea level. The relics of gigantic birds prevail in the fauna of New Zealand as in all the new southern lands, to the almost entire exclusion of mammalia and reptiles, accompanied by ferns and club-mosses, thus showing that it had not been as yet connected with a pre-existing continent, with quadrupeds and other terrestrial animals.

Should New Zealand subside and be emerged again, it would be inferred that its organic remains belonged to another world that did not contain any other animals than the relics represented. This island presents a general correspondence with the lands of the carboniferous epochs, and is strongly impregnated with carbonaceous liquids, which crystallize into seams of bituminous beds. The same kind of productions are only seen in Van Diemen's Land and many parts of Australia, and used as coal.

Australia and Van Diemen's Land, in consequence of the abundance and variety of the cycadeæ, araucariæ, &c., the marsupial character of the great proportion of the mammalia, and the terebratulæ, trigoniæ and the cestraceous fishes which swarm in the seas that wash their shores, produce deposits with relics like those we find in the carboniferous and oolitic formations, which will hereafter become sedimentary rocks like those now seen in Europe.

THE DEPOSITS OF THE TORRID ZONE.

The portion most available for examination in this zone, with the exception of a part of India, is South America. Here we have the advantage of a very extensive and continuous series of sedimentary beds, which can be traced, more or less, from the south, to the shores of the Caribbean Sea. These sedimentary rocks are intersected by very deep ravines, presenting every facility for making minute examinations.

The author has made numerous large Sections, one of which is shown in Plate VII. He presented the Geological Society with some of the fossils in 1843 which are described in the Geological Proceedings, vol. IV., No. 101. This section represents the rocks near the equator, where the series of sedimentary beds can be well seen; they are largely developed, and elevated to about 11,000 feet above the level of the sea.

Commencing the examination below, we find the usual, and indeed universal base, *i. e.* various bands of crystalline rocks on edge, and running north and south, on which the sedimentary beds are formed, in some places as beds of sand, and in other parts clay, pebbles, or large boulders with but very slight traces of organic remains, varying according to the nature of the locality and sea bottom on which the beds were deposited.

Ascending the series, we come to beds of sandstone and clay-slate, more consolidated than those of the previous zone, but containing shells so much like those found in the South Temperate Zone as to render it impossible to separate them as a whole. We next come to a series of sandstones, dark compact limestone and seams of coal, with impressions of plants in the shale and clay presenting more of the South Tropical aspect than that of the Torrid Zone.

The shells, corals, and ammonites are somewhat abundant in this formation, some of which have been described by the late Prof. Edward Forbes*. The living representatives of the ammonites have not been discovered, but the other shells, nautilus and corals, are analogous, if not identical with those seen in the southern seas.

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* Geol. Proceedings, vol. iv. No. 101.

The upper beds of this formation predominate in sandstone, which are somewhat barren of organic remains; but in the debris over the surface and in the ravines are found a great variety of ammonites, varying from an inch to three feet in diameter, with oyster and other shells, fossil wood, and fossil bones of gigantic saurians and other animals.

These are found along the plains for many hundreds of miles north and south of the equator.

In the gravel beds, are also found the remains of crocodiles, sharks, fossil trunks of large trees, and of the plants which are still living in South America on the banks of the Amazon, Orinoco and the Galapagos Islands.

When we take a general view of the physical conditions in which we find the above series of sedimentary rocks and which form such a large portion of the eastern branch of the Cordilleras, for thousands of miles north and south, we cannot arrive at any other conclusion than that the deposits were formed in inland seas, that the whole has been gradually and somewhat uniformly elevated to the present height (say 11,000 feet above the level of the sea), and that such continuity—unbroken beds for so many miles in extent—could not have been produced by volcanic eruptions, or any other convulsive force.

Indeed, had geologists the opportunity of witnessing the constant mutations now going on along the coast of South America by the slow and imperceptible elevations and subsidences, causing great geographical changes, they would have no reason to have recourse to their favourite theory of prodigious cataplasms, or paroxysmal upheavals by internal fires.

On minutely examining the beds, we do not find the organic separations and the common breaks established by geologists; on the contrary, we see a gradual transition from the inferior to the superior beds in their organic contents; hence, to produce such deposits as we find—and admitting that the organic conditions of the respective zones have remained unaltered,—it requires two movements, viz., a vertical one from the level of the sea, and a *longitudinal one from the southern zone,* to account for the apparent difference of the organic contents of the deposits below as compared with those above.

If we admit one movement, viz., the vertical oscillation, there can be no difficulty in admitting the horizontal or oblique movement, especially when we find that it is the only way by which we can account for such variable organic deposits according to the existing laws in the œconomy of nature.

Further proofs of the necessity and the real existence of the two movements will be found as we progress in our inquiry. It may be argued, that the south currents, explained above, would alone be a sufficient cause to account for the organic remains of the south being deposited at the equator and northern region. The oceanic movement from the south doubtless explains the origin of some deposits; but those which indicate that they have *lived and died on the spot in which they are now entombed,* require an action different to that of mere currents of water. The lands as well as the ocean must also move *en masse* to account for the phænomena.

In Malacca, Singapore, Borneo, Sumatra, Java and Ceylon, the sedimentary rocks are but slightly developed, forming a small and very partial covering, on the edges of the primary rocks; the organic remains, as far as they have been examined, correspond with those existing in the Indian

Ocean and Southern Islands. Scarcely any organic remains are found in the ferruginous beds of Malacca; the primary rocks here are almost bare. In the Indian Peninsula, and more especially in Bengal, there is almost a total absence of fossiliferous rocks, and the coal-basins are found, like those of New South Wales, deposited immediately on the edges of the gneiss and schists, first as beds of conglomerate, then shale, limestone and coal, with ferruginous clay beds without any trace of the Cambrian, Silurian and Devonian rocks of England. The slight impressions of plants, that can be detected in the clay seams and shale, are analogous to the ferns of the south temperate region already explained. This portion of the Torrid Zone has a greater number of breaks, &c., than that in South America, and is consequently more subject to diversified deposits. The Philippine Islands contain small carboniferous deposits, but generally speaking these islands present the usual variety of crystalline rocks, uncovered by sedimentary beds.

The Malay Peninsula, Ceylon and Hindoostan, have only a few isolated patches of sedimentary deposits, and although they do not contain any large amount of organic remains, those detected correspond with the marine and terrestrial fauna and flora of the Southern Hemisphere. Arabia and Africa, so far as these countries have been explored, are but slightly covered by sedimentary rocks. There are beds at the Cape of Good Hope, which more or less correspond to the carboniferous, and conform in some degree to the configuration of the bend which the current of the ocean has at this point. The interior of Africa, like that of Australia, appears to predominate in a sandy desert. The isthmus of the Darien, Guatamala, and the West Indies, are also somewhat scantily covered by sedimentary beds.

The Coral Islands and Reefs of this zone deserve our particular attention, as showing how the calcareous springs, &c., are collected and deposited at various centres in the ocean. The corals live and flourish from the very margin of the south polar basin even and extend to the north Temperate Zone, but it is in the southern portion of the Tropical Zone that we find them growing like forests of stony plants, from the forms of sponges and mushrooms to that of gigantic cauliflowers and trees. The Indians, or the natives of the hot countries, call corals "sea-plants" and "rock-flowers," and smile at the idea of their being considered as the production of marine animals.

Corals are, as it were, protected and cultivated at Ceylon, the islands in the Pacific, and numerous other places, for the purpose of obtaining lime from them, where limestone beds do not exist. In and near Torres' Strait there are many coral reefs; there is one extending from Breaksea Point, on the eastern coast of Australia, to Briston Island, off the coast of New Guinea—a distance of 1000 miles more or less in the meridian, and 30 miles in breadth. This reef is growing on one of the ridges of the primary series.

There are several others of the same character running between the north coast of Australia and New Guinea, which are infested by gigantic sharks. Shells of large size and great beauty, including several species of the nautilus, are found in this region, and are daily buried in the sand and calcareous mud of the lagoons, forming oolitic and cretaceous beds for future generations.

The corals of the Maldive Islands grow on high ridges of the primary slate, from Chagos to the coast of Bombay, about 23° of lat. The edges of the primary rocks, and especially the gneiss with hornblende bands, appear to be peculiarly favourable to the growth of corals, when they approach within a few fathoms of the surface.

Many of the coral islands called *Atolls*—such as the Keeling or Ross Island in the Indian Ocean—are formed by the cones made by submarine freshwater springs; hence they are favourable spots from whence to obtain this desirable element in the Torrid Zone in the middle of the ocean. It is true, that some of these submarine springs, on their first bursting out into the saline compound, appear to have become inflamed, and to have melted the rocks on the margin of their passage. Such was the case during the emersion of the Island of Taboga, near Panama in the Pacific; but this inflammatory action (which is probably produced by the hydrogen and chlorine) is the exception; upwards of 96 per cent. of the coralline islands being produced by the aqueous springs of fresh water alone. These latter are very numerous in the Hebrides and the Caroline Islands. The growth of corals extends as far north as the Bermudas, owing probably to the warmth of the Gulf Stream. They are found in great masses in the Caribbean Sea. The island of Barbadoes is a consolidated mass of coral.

Portobello has been entirely built of coral rocks that grow on the hornblende rocks of that coast. Corals contain from 90 to 95 per cent. of lime, and may be truly called calcareous plants.

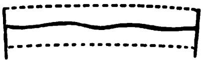
It is a very interesting fact, that the action of the sap of corals, vegetables, and the oscillations of the tidal waves, accompany the changes of the moon as regularly as clockwork, within the tropics; these important facts, together with the diurnal oscillations of the barometer and the magnetic needle, will be noticed separately with various other meteorological phænomena.

In connexion with submarine cones forming what are called Atolls, which are fringed with corals, it would not be irrelevant to notice also the sub-aërial cones of similar character, which are called by the Spaniards "volcanoes de agua." A very interesting example may be seen near Carthagena in New Granada.

The superficial formation is principally composed of coralline rock, partially changed into a porous calcareous crust, and mixed in some places with sand, gravel and seams of sulphate of lime.

On this formation are the celebrated "volcancitos of Turbaco," which are small cones, situated on a rising ground, discharging aqueous and gaseous matter. They appear to have been produced, and are still partially kept in action, by springs of water confined underneath by the calcareous cap. Each of these miniature volcanoes has a bubbling action, but the temperature of the water is not higher than that of the surrounding air, say from 86° to 100°. The water has a saline taste, and is slightly aperient; it contains carbonic acid and sulphate of soda. The mud discharged and deposited on the margin of the cones and craters, is very black. Nicaragua contains also many "volcanoes de agua"—it may be stated as a fact that the Western Hemisphere predominates in them—scarcely containing 2 per cent. of the igneous variety when in a state of activity. Indeed, the fiery cones are the exceptions in all parts of the globe: they only become inflamed, when disturbed by local chemical causes, whereas the aqueous cones are innumerable and almost everywhere, and are always active, supplying the sea, the vegetable and the animal kingdoms, with many of the essential elements from the interior of the globe.

The apparent disturbing action of these springs and their varied productions from pure cold water to impregnated mineral compounds have not been sufficiently attended to; far too much importance has been attached to the exceptional phænomena of incandescent volcanoes, in questions connected with geological dynamics, which are, after all, when compared to the size of the globe, but mere microscopic pimples. The annexed diagram exhibits the undulation of the surface from the highest mountains to the deepest seas, in proportion to a portion of the globe 500 miles in length.



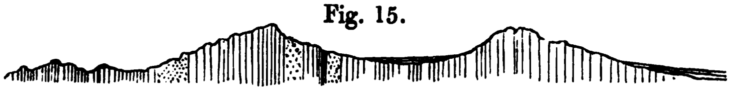
The Sedimentary Rocks of the North Temperate Zone.

This division will embrace North America, from Mexico to the Arctic Regions, Europe, Asia and the northern portion of Africa.

On reference to the general view of the two hemispheres, it will be observed that the sedimentary series of rocks is more developed in this zone than in any other portion of the globe, but more especially in Europe.

Commencing our investigations on the shores of the Pacific, we find the primary series only very partially covered by sedimentary rocks along the coast of California. To the north, in Vancouver's Island, there is a carboniferous formation with impressions of plants analogous to those now flourishing in Chili. The following transverse section from the Pacific to the plains of the Missouri, will give an idea of the primary series, and the superficial sedimentary covering.

Fig. 15.



The primary rocks are more or less exposed from the Valley of the Sacramento to the east flank of the Sierra Nevada, and are traced on edge running north and south for hundreds of miles—like the structure of all gold regions, and only covered by the crystalline debris. Between the Nevada and the Oregon Mountains, the surface is covered by the debris of the primary rocks and sand; in this basin are numerous saline lakes. The Oregon Chain to the Rocky Mountains is composed of the usual series of primary rocks on edge running more or less north and south, from Mexico to the Arctic regions; and on descending eastward towards the plains of the Mississippi and the Ohio, the whole is thickly covered by deposits of comparatively recent origin, enclosing bones of the mastodon and the buffalo. The mountains of the Sierra Nevada, especially in Nappa, have numerous "volcanoes de agua." The apertures in the mountain sides frequently resemble the Geysers of Iceland in the roaring and hissing of the vapour issuing from them. In some, the bubbling waters are so hot as to scald the hand, while not far distant, springs discharge water almost as cold as ice. Mineral springs of all kinds abound in this region—sulphur, alum, carbonate, and chalybeate waters. A piece of wood placed in one of these springs soon becomes encrusted with silica and calcareous matter. Bituminous springs form also beds of jet, and crystalline beds of a dark carbonaceous substance. The process of the formation of limestone, from calcareous springs, can be seen going on daily in these regions, similar to that now forming in various parts of South America. Salt is also found in large masses, on the plains between the great ridges.

A gentleman who had visited the above region writes—"The fountains lay open at one view, the extraordinary operations of subterranean heat caused by chemical action, instead of the mistaken idea of volcanic fire or igneous globe. In one place, about 40 miles from the mountain first above mentioned, one of the party broke open a hard rock of shell limestone, and found in it a perfect shark's tooth with serrated edges precisely like the living species of the Pacific coast. In another place he broke open limestone more recently formed, in which were enclosed land snails or helices, with perfect shells, and petrified trees, &c."

The fluviatile deposits of the Missouri and Mississippi contain land and fresh water shells of local species, with a considerable proportion of tropical productions.

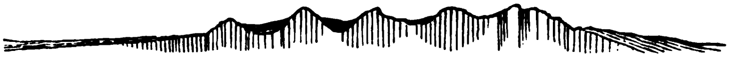
It is extremely probable that the Gulf Stream ran formerly in this direction to the Arctic Regions, and thus conveyed a large amount of tropical vegetation, &c., and deposited the same in the mud of the valley of the Mississippi. Very great changes have taken place during the last 250 years from the Isthmus of Panama to Florida, the whole of which is still rising. Both the Isthmus of Panama and the Isthmus of Suez are covered in several parts with shells belonging to the South Pacific and the Indian Ocean; thus showing that their emersions respectively are, geologically speaking, of a recent date. Drifted productions of the tropics and the Southern Hemisphere, carried by the oceanic stream northward,—in various directions, according to the altered configuration of the dry lands, may,—it is true, account for a great many of the organic remains which we find in the deposits of the Northern Hemisphere; but such operations are not sufficient to cause an entire south tropical forest, with its accompanying animals, to be conveyed to the north, and to become gradually enclosed there in sedimentary beds of different climes and periods; neither are these merely isolated effects: they are found to prevail throughout the northern hemisphere in North America, and in Europe, to the confines of Asia and the north polar basin; therefore nothing less than a movement *en masse* northward, carrying forward all the organic system with it from zone to zone, can account for such phænomena as these. These deposits are not irregular or at any time inverted, such as the deposits of the north lying under those of the south; on the contrary, we first find underneath the deposits of the southern products, then of the tropics, and lastly those of northern latitudes, one on the other, in succession and strictly in accordance with the result of a movement from the south to the north; thus we find the land conforming to the direction of the general movement of the ocean. In discussing questions like these we must dismiss from our minds the *present* geographical distribution of sea and land, and bear in mind the numberless elevations and depressions of the land that must have taken place, since the creation or the commencement of the older sedimentary deposits which have been brought from the south, and which are now merging into the north polar basin.

Proceeding eastward towards the Appalachian Range, the carboniferous deposits are found developed in long trough-like shapes, nearly parallel to the bordering primary ridges. Some of the coal-beds are about 35 feet thick. The carboniferous basin of Eastern Virginia is composed of sandstones, shales, &c., deposited on hornblende, slate and granite.

The sedimentary deposits of the United States, Cape Breton, &c., contain upright stems of Calamites, Equiseta, Lepidodendrum, and a great variety of Ferns, similar to those found still growing in Patagonia and the Brazils; and their fossil condition shows most distinctly, that *they grew* *on the spot where they are now entombed.* Many of the fossil trees were also hollow before the mud—which now forms the shale—was accumulated round the plants. Hollow trees are peculiar to the South Tropical Zone: in Patagonia and Australia, whole forests of hollow trees are very common.

The following section will give an idea of the structure of the eastern part of the United States, across the Appalachian chain of mountains.

Fig. 16.



The Americans have subdivided their sedimentary rocks somewhat differently to the Europeans, and as their deposits (stratigraphically) do not correspond with the sedimentary beds on this side of the Atlantic, they have a right to adopt their own local systems, provided they do not carry them beyond their proper limits. It is, as already observed, very injurious to the progress of geological science to attempt to form general systems of equivalent deposits which could not possibly have existed under the various distribution of sea and land, and the numberless elevations and depressions going on. The proofs of such changes are incontestable, showing how necessary it is to bear in mind that the altered physical conditions, at different periods, influence the character of the local accumulation of detrital matter. However convenient the subdivision of beds may be for local purposes, such a partial system should be avoided in discussing general questions; we should adopt a much larger grouping, when we compare the deposits of distant regions with one another, even in the same parallel of latitude, much more when we examine the deposits of different zones, at different intervals of time.

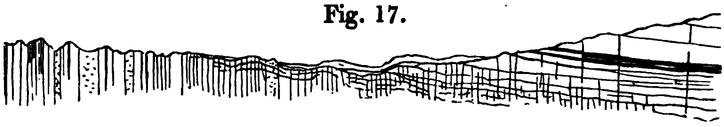
For our present purpose it is sufficient to state that the sedimentary beds of the United States, from the lowest to the highest, contain the organic remains which correspond with the South Temperate Zone and the tropics; and that *these remains lived and died on the spots where they are now found, at the time of their deposition, and when the land was in more southernly climates.*

The primary series is seen more or less on edge in this part of the States, and can be traced from Florida along the Appalachian Chain, to Canada, Nova Scotia, &c. The same kind of primary structure is also seen north of the Lake Superior; but as this subject has been already noticed, we shall proceed to the consideration of the formation of Europe.

The Sedimentary rocks of Europe have been so attentively examined, and so carefully divided into several systems of deposits, that it is only necessary to name the principal groups in the ascending order, and to note the character of their enclosed organic remains, to serve the object of this introductory discourse.

These groups are called the Cambrian, Silurian, Carboniferous, Oolitic, Cretaceous and Tertiaries. The annexed section will show their relative position, and the effect of the vertical structure of the primary series, in obliterating, intersecting, and contorting the old sedimentary beds below.

Fig. 17.



In examining the organic remains of Europe, we find precisely the same indication of a change of climate from the south to the north as elsewhere; the fossils are not simply the relics of drifted organic remains from the south, but gigantic plants of the Southern Hemisphere, in a perfect state of preservation, with their roots still attached to the consolidated soil; which may be seen in the coal formations of England, Bohemia, Saarbruck, &c., in the positions in which they grew: many of these plants cannot be distinguished from those still existing in Australia.

Dr. Hooker's observations on this subject fully bear out the analogy.

The *order* of succession above indicated is found to be constant all over Europe. Not that all the members of the series are universally diffused and always present; on the contrary, there are but few spots where the *whole roll* of the sedimentary rocks is seen lapping one on the other without a break; yet the ascending sequence is invariably the same. The *organic aspect* of the Cambrian and Silurian Systems is not by any means different to the present aspect of the zone bordering the Antarctic region. The latter zone presents a barren and desolate scene: nothing but a few shells and corals can become deposited in that portion of the globe. The genus Serolis is a near approach to the external form of Trilobites, and the beach in the Straits of Magellan is often seen covered with dead Serolis, which are only found alive by dredging in deep water. Many of the broken shells and corals of this desolate region have a striking resemblance to those found in the Silurian rocks. On ascending to the Carboniferous system, the organic aspect changes almost abruptly, from a scene of marine barrenness—mere shells and corals—to that of a lacustrine and terrestrial vegetation of a semi-tropical character, and consequently somewhat abundant in organic remains; thus indicating the most complete accordance with the varied conditions and great contrast between the organic systems of the Antarctic and the South Temperate Zones.

Were a Patagonian geologist to come to Europe to examine the contents of the sedimentary beds, he would not be surprised at seeing the different organic aspects of the beds, nor would he assume the unnatural conditions of the universal spread of each of the organic systems, with repeated destructions and new creations, but would be governed by the existing order of things and natural analogies, and would necessarily attribute the change to what he was accustomed to in the Southern Hemisphere. There is no spot on earth where the deposits could obtain in the same region an assemblage of all the existing organic kingdoms. Every region from zone to zone, and from the bottom of the sea up to the inferior limits of perpetual snow, has its peculiar fauna and flora; therefore why should we conceive the existence of a different order of things in ages gone by? Since such is the law of the organic distribution, it is quite evident that nothing short of a progressive movement of the land from zone to zone, *i. e.* from south to north, could produce such a collection of organic remains as those now found in the sedimentary rocks of Europe. Every day is adding to our knowledge of the varied distribution of the living system, and the perpetual disturbing and renovating action of the Earth's surface, by submerging and emerging from the level of the ocean. During the past epochs, when our oldest rocks were deposited, the same physical laws prevailed; therefore why should we invent unnatural systems, when we find that the laws of existing nature account for all the phænomena we observe in our rocks?

It would be as unnatural to find cocoa-nut trees and bamboo mixed with the organic remains of the Silurian rocks, as it would be to see pine-apples and sugar-canes growing in the open air amongst the cabbages and potatoes in the northern region. If then we name each system of sedimentary beds according to the zones in which it is herein assumed and maintained that the beds were originally deposited, we find all the apparent discordances and difficulties vanish, and the whole at once presenting a complete and consistent natural system of deposits. Let us take, for example, the following European series of sedimentary beds, from the Silurian to the Tertiary, and compare their contents with the deposits now accumulating in the respective zones.

Local names.	Zones where the beds were deposited.
1. Silurian	Antarctic.
2. Carboniferous	South Temperate.
3. Oolitic	Ditto ditto.
4. Cretaceous	South Tropic.
5. Tertiary	North Tropic.

On reference to each system of beds, it will be observed that there is a perfect agreement between the organic aspect of the deposits and the existing state of things, and that a slow undulating movement of the surface of the earth in transit through different climes, in conformity with the polar force and the movements of the ocean, would produce the results observed.

The oolite formation presents the South Temperate aspect in all the beds. The crocodile, scorpion, and other reptiles, and fishes corresponding to the south have all been found, not only in the lias and oolite, but also as low down as the coal formations on the Continent. At the period of the lias, the vegetation was similar to that of the Southern

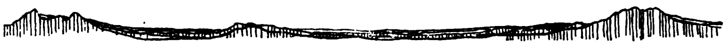
Hemisphere, not only in the simple fact of the presence of Cycadeæ, but the pines herein imbedded were also of the nature of species found only to the south of the Equator.

It is not in strata where the organic remains belong to extinct species, but where the living species abound in a fossil state, that the question of a gradual geographical change can be subjected to the *experimentum crucis.* The fossils of the Subapennine hills, and their living analogies from the tropics, correspond in size; but the individuals of the same species from the Mediterranean, are dwarfish, and appear degenerated and stunted in their growth, for want of the physical conditions which the Indian Ocean still supplies. Whenever any of the fossil shells are identified with living species at or near the Equator, it is not in the Northern Ocean, but in the Southern Ocean, that they must be sought. The same may be said with respect to the fossil sharks in the sandstone beds of Malta.

We need but refer to the description of the sedimentary beds of Europe and Asia, and their organic contents, to obtain the evidences of a northward action throughout.

To the north—in Scotland, Norway, Sweden, Iceland, the Ural, and part of Siberia,—a great portion of the primary series is uncovered by sedimentary rocks. In Norway, Sweden and the Ural, the primary rocks are found in their normal position, on edge, and running more or less north and south. The following section will give a general idea of the formation, from the west coast of Norway, to the plains of Siberia :—

Fig. 18.



The elevation of Russia has been remarkably uniform and gradual, and the sedimentary rocks not disturbed and dislocated like those of Western Europe in the Alps, &c.

Volcanoes.—Although Vesuvius and Etna have been very active igneous incandescent volcanoes, we find that they are the exceptions in this zone as in other parts of the world. The volcanoes of Iceland may be traced from mere springs to gigantic cones. The Geysers may be divided into two main groups, according to their chemical properties, one of which comprises the acid and the other the alkaline silica springs. The springs are found hot and cold, and contain soda, alumina, silica, chloride of sodium and sulphate of soda.

The hot springs of India are the same; and in short, all the pores or terrestrial pimples, from the size of a mole-hill to that of the magnitude of a volcanic crater, are only different in their dimensions, and not in their aqueous character, being the effects of active local condition, generated by the elements of the sea and the crystalline base. The volcanoes are commonly found in meridional lines in the direction of the primary structure, as Etna and Vesuvius, and the directive force of Earthquakes follows the same course. The undulations and vibrations of the surface are frequently propagated along the primary structure from Chili to the Caribbean Sea, a distance of many thousand miles.

The Arctic Region.

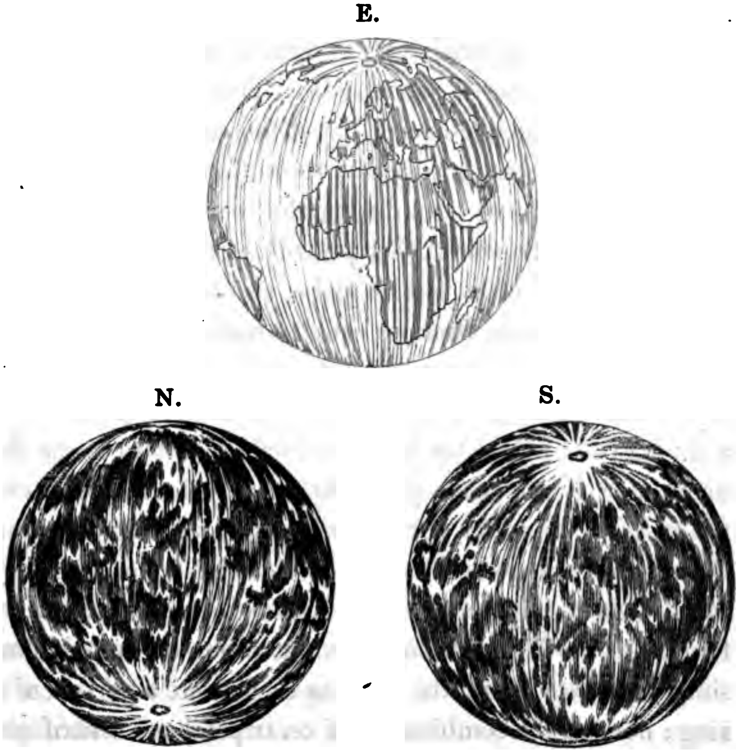
We can only examine the margin of Europe, Asia and America in this region; still even here we find sufficient proofs of the changes which have taken place on the surface of our globe.

Greenland, a thousand years ago, enjoyed a mild climate and contained a large population.

Numerous subterranean stone labyrinths have been discovered in Lapland, Nova Zembla, Spitzbergen and some of the islands lying near the coast of Finland, particularly in the desert of Wiez, giving strong proofs of former habitations in these dreary parts, that have so long since passed into oblivion. Trunks of trees, with their roots attached to the soil, proving that they once grew on the spot, have been found far in the Arctic region; stems of Palms, and Elephants with their skin and hair still preserved, are found buried in the interior of the earth in Northern Europe and Asia. Numerous other evidences may be brought forward to show that great changes have taken place during our historic period, and that these movements are still constantly going on, carrying the lands to the inhospitable clime of the north; their respective inhabitants either dwindle and perish, or retrograde southward like their predecessors. Hence the cause of the world being always populated from the North. The sedimentary rocks that have been examined on the west coast of Greenland, Baffin Bay, Melville Island, &c., contain marine shells and terrestrial plants analogous to those which are still flourishing in the South Temperate regions.

Having now glanced over the universal character of the sedimentary rocks of each zone, we shall next draw attention to the general aspect of the globe, when viewed in connexion with its poles, primary structure, the oceanic streams, and the white aërial luminous meridional bands which are often seen stretching from pole to pole, on clear nights, within the tropics, during the period of the polar lights. Were it possible to view this phænomenon at a distance, the globe would appear at times like a gigantic fruit or a melon with its meridional bands or polar structure.

It is also a fact, that our satellite presents the same kind of fruit-like appearance similar to the radial symmetry of an orange near its stem, as will be seen on reference to the following sketches, which represent a telescopic aspect of the moon. [The Frontispiece plate is an exact representation of the Moon as seen from the Southern Hemisphere.]



E represents the earth with its north pole towards the Sun (in June); N the Moon as seen in the meridian from Europe; S the Moon as seen from Van Diemen's Land.

The visible pole of the Moon (which is always pointing to the south pole of the earth) is very striking, and the meridional or polar structure, or rather the luminous meridional bands, are beautifully displayed in the clear atmosphere of the tropics, showing very plainly that our satellite is governed by the same law of polarity as our earth. The sketches are only intended to represent the general aspect and the different position of the pole of the Moon as seen from the north and south*. According to the well-ascertained laws of Magnetism, the visible pole of the Moon must be her north pole, and therefore it serves as a very interesting spot, to enable us to form some idea of the appearance of our north polar basin. This angular position of the Moon is analogous to that of the earth, consequently the Moon's Seasons during her revolution round the earth must be the same as ours during the year.

It may here be stated that polarity alone is sufficient to flatten the poles of an elastic globe, and to increase the intensity of the forces from its equator towards the extremity of the axis. Indeed, according to observations and experiments made during the growth of spheroidal tropical fruits, a similar polar action has been detected; the stem forms the north, and the opposite point the south pole, from whence the gases evolve with a circular action back again to the stem. See also the orange and the apple. Rotation is not necessary to produce a spheroidal figure, as may be observed on reference to the Moon, which does not rotate on an axis, but simply revolves round the earth as if she were a portion of a ring; nor can the combination of centripetal and centrifugal forces produce the variation we find in terrestrial attraction by the pendulums, &c., from the poles to the equator. Theory and observation have never agreed on these points. According to barometrical observations, we find the height or pressure of the atmosphere about $\frac{1}{30}$th less in the polar regions, but of greater density than at the equator.

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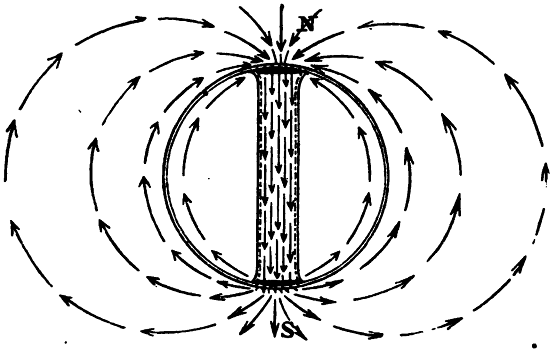
* For a more perfect representation of S, see Frontispiece.

The terrestrial magnetic force alone accounts for the whole phænomena strictly as observed.

We find by experiments that a magnetic force cannot exist without a *continued action*; consequently the magnetic needles, like the wind vanes, are merely the indicators of the polar stream, and that this stream is constantly moving from the south pole to the north, and, according to experiment and analogy, completing the circle of activity through the medium of the axis. This fact is proved daily by the action of the magnetic telegraphs.

Fig. 19.



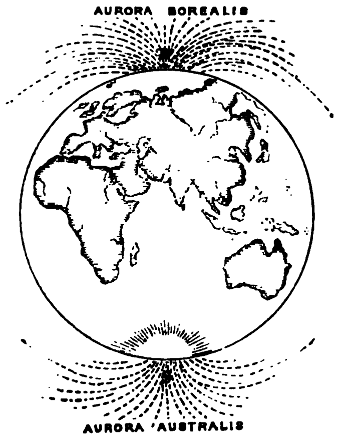
In making experiments with solutions of various minerals, under the influence of magnetic currents, from pole to pole, we find that although the circuit of activity is completed and kept up by means of the magnetic axis, yet the substances never pass through.

It is only the hydrogen,—the active spirit as it were, that passes through the axis, or the wires out from the south pole and in again at the north pole.

The various terrestrial substances which this subtile power controls and modifies on the surface of the globe for the uses of the organic kingdoms, are dissolved and left behind in the ocean at the north polar basin to be reproduced again from the ocean at the south pole. Thus the action is perpetuated; the changes of the surface with the very same elements are continued, and this effect can be proved and imitated by means of a magnetic battery, with solutions in the decomposing trough.

The minerals and the waters may thus remain for ever fulfilling their offices without causing any disorganization in their general character, as liquid compounds or crystals; but such is not the case with the organic kingdoms. The latter must retrograde continually southward to suitable climes, and be provided with a sufficient area of dry land in each zone to be preserved, otherwise they would all become by degrees extinct, which has been the case with many species and genera since the Creation.

Fig. 20.



With regard to a magnetic globe, we find also by experiment that its attraction is the same whether the globe be solid or hollow, provided the area of the section of the axis be equal. Therefore no idea of the nature of the interior can be formed by experimenting on the external attraction. This important fact is not sufficiently attended to by mathematicians engaged in attempting to ascertain the density of the earth.

The great changes, in and on the surface of the earth, (however slow and imperceptible may be the subterranean force that produces them), must constantly alter the relative positions of terrestrial points as compared with the heavenly bodies. We have found by astronomical observations that such changes are going on, and that they destroy, in the lapse of a moderate number of years, the arrangement of the catalogues of stars, and make it necessary to reconstruct them. Since the formation of the earliest catalogues on record, the place of the equinox has retrograded about 30 degrees. This change is called the "Precession of the Equinoxes," which was only discovered about 110 years ago, when the surface of the earth was considered as fixed and immoveable; and consequently to account for the apparent alterations then detected, astronomers were obliged to assume a bodily movement, *i. e.* of the whole globe. No movement in the *geographical position of places* could be entertained, nor has it been suspected until it was announced by the author some years ago, and partially proved by astronomical observations in South America. The idea of the earth moving, elevating and depressing, appear in open and striking contradiction to the evidences of the senses, and in opposition to the ideas of common observers, but not more so than those of Astronomy. The latter science has demonstrated that the earth on which we stand, and which has served for ages as the unshaken foundation of the firmest structures, either of art or nature, whirls on its axis daily, and revolves round the sun annually. Geological science now demonstrates that the very surface of the globe has *an undulating and polar movement*; and thus the earth, the seat of man and his works, is completely divested of all its attributes of fixity. These must necessarily appear startling announcements to those who have not studied the natural operations of the world; nevertheless they are not less true, and are capable of being tested and proved as substantial facts, although they may be received as reluctantly by the world as the daily rotation of the Earth was received at the time of Galileo, and will perhaps be opposed for many years; but such is the fate of all systems that happen to be contrary to our preconceived notions, which nothing but time, experience, and the removal of prejudices and untenable doctrines can correct. The daily rotation of our globe was not known until it was announced by Galileo, and many plausible arguments were brought forward by astronomers and mathematicians to prove the impossibility of such a rotation. It was a long time before such an idea could be reconciled, as it appeared contrary to the evidence of the senses; besides, the very fact of the terrestrial pole always corresponding to the same stars was held as a sufficient argument against the revolution of the globe round the sun; ultimately the rotation was accepted, and it enabled astronomers to understand better the movements of the planets than they did before that period, although they made no difference in the astronomical calculations.

In entering into this question, it would be well to acquaint those who have not studied ancient geography, astronomy and physical science, that the configuration of the land, as now represented on our globe, is of a very recent date, and does not, by any means, agree with Ptolemy's observations or the ancient maps of the world. Indeed, we find the changes so rapid in the Southern Hemisphere as to render it necessary to make frequent periodical surveys and new charts. Even so recently as the commencement of the last century, the position of some of the European *Observatories* could not be depended upon within twenty minutes. What then must be the errors of places less favoured by proper surveys, and permanent advantages for scientific observations! When Bradley first discovered the variation in the apparent position of the fixed stars, he attributed it to motion in the imaginary pole of the heavens itself.

Further observations led him to abandon this theory, inasmuch as direct observations did not confirm it, and it was subsequently referred to a slow conical oscillation of the earth bodily, which theory, for the want of a better, and in the absence of any knowledge of the superficial changes above alluded to, is entertained to this day by astronomers, although incorrect in its application.

This phænomenon is called the "Precession of the Equinoxes," owing to the imaginary points of the intersection of the Equator and Ecliptic continually varying at the rate of $50''$ per annum, thus changing the relative position of the fixed stars. Movements of this description, be they terrestrial or celestial, produce similar relative changes, and may be made to conform to any theory, if the calculations be founded on the *geometry of the paths of the heavenly bodies*, which are the true elements of Astronomy, and not Physics.

The ancient astronomers, with their theory of a fixed globe and the revolution of a celestial vault, calculated the period of the eclipses, &c. as we do now, without the aid of modern theories and refined instruments. This shows how little our *physical* theory of the heavenly bodies has to do with the question, and how much we have been misled in various scientific questions by the mistaken infallibility of mathematical theories, and by substituting the laws of geometry for those of physics. The physico-geometrical laws have encouraged the search for perpetual motion, and have led many of the greatest deductive mathematical philosophers to become atheists, from the false assumption that motion required no constant active principle, nor the aid of the Prime Mover of all things to govern the order and circular arrangements of the Universe.

Our Nautical Almanack entirely depends on the correctness of constant observations and calculations founded on uniform movements and on the geometry of the paths of the heavenly bodies, and not on any physical theory of the system.

So also with our tides, and numerous other terrestrial phænomena which could be mentioned: they depend on classified facts and periodical observations.

Therefore we must not imagine that our astronomical physical theories are infallible, or that they are beyond correction in their *physical* deductions. Had Kepler been acquainted with the laws of terrestrial refraction,—had he known that the variable diameter of the sun was an optical illusion arising from its variable angular position in the atmospheric lens, and not that its distances from the earth varied,—he would not have made the annual orbit into an ellipse: or had astronomers existed at the same time at the Antipodes, they would have corrected the error by stating that the variable diameters of the sun to them was quite the reverse to that observed in Europe, and that the sun appeared large to them in June and small in December. Yet this notion is still encouraged by our astronomers; but fortunately as the mean diameter of the sun is generally employed, and that nearly agrees with the observed diameter at the angle usually taken to determine the longitude, it does not lead to very material errors*.

To return to the question at issue respecting terrestrial changes, it may be stated that a gradual spiral movement of the earth's surface towards the North polar axis, at the rate observed, will strictly account for the phænomenon of the Precession, and in a much more satisfactory manner than the present theory of a bodily oscillation of the globe. Indeed Bradley was never satisfied with this theory, inasmuch as the observations did not agree with such a movement; but for the want of a better, with the usual aid of corrections for nutation, aberration, refraction, &c., it has been, like the theory of the tides, preserved amongst our scientific records more as a memorial than for scientific utility. The comparatively short period which has elapsed since the above change was first detected (about 110 years ago), the exceedingly slow rate at which the changes take place, with the strong bias for the preconceived geometrical theory, with all its imperfections, rather than accepting any new principle, all have precluded the possibility of determining, with any degree of accuracy, the actual amount of the movement along the meridian; but it is to be hoped that this very important question will no longer be neglected. However, it is sufficient for our present object to state that the movement of the surface towards the north pole, since the change has been discovered and compared with the ancient catalogues of the stars, has been at the rate in round numbers of about 20 seconds per annum—1 minute in 3 years—or say 1 degree in 180 years; the rate of movement may be a trifle less, but cannot be more. Near the pole the variations in the position of the stars are very considerable: the tables only serve for a few years; hence nearly all astronomical computations are obliged to be reduced and measured from the centre of the earth; thus astronomical errors arising from the instability of the surface are avoided.

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* In latitude 40° south, on the 2nd of June, 1852, I drew the attention of Capt. Smith, of the Futtel Oheb, to this subject, and requested him to make direct observations to prove the correctness of my observations and tables of diameters and refraction. The Nautical Almanack indicated a diameter of 31′ 34″. The meridian altitude of the sun was 22°, and its actual apparent diameter was found to be 32′ 22″, being a difference of 48″, thus causing an error of several miles in taking the longitude. The captain became so convinced, that he determined in future to be guided by the variable diameter of the sun according to its angular position; and I would recommend all others to do the same in taking astronomical observations in the Southern Hemisphere. Astronomers freely acknowledge that the laws of atmospherical refraction are still very unsatisfactory. The cause of this uncertainty affects some of the most important *data* of astronomy, and needs but direct observations to be corrected and established like the laws of optics.

Supposing this movement of the earth's surface from the south to the north to be constant, it follows, that at the above rate of progression, the spot on which London now stands must have been in the equator about 9180 years ago; and that the whole of England will be within the Arctic circle in about 2800 years hence.

According to the ancient records of the Egyptian priests, the sun was to the north of Egypt since the commencement of the dynasty of their kings; also some of the stars, which are now south of that country: and at a still more recent period, the sun was seen in the zenith of a certain well which is now situated very far to the north. Although the observations of the ancient philosophers have been lost in the lapse of ages, the records of the past history of the earth have been laid down and preserved by a power beyond the reach of human control and imperfections; hence Geology may recall the past and anticipate the future by means of direct observations and its organic remains.

To conclude, the great undulating movement of the crystalline film, its various deposits and saline covering, governed by the constant presence of that power called polarity or magnetism,—moves from pole to pole, carrying everything with it. This power renovates the surface of the earth to suit the wants of successive generations of animated nature in all ages. Our globe is not the result of chance, or of any imaginary compound of wrecks and confused chaos thrown into space by the rotation of an incandescent sun, then moulded and sustained by centripetal and centrifugal forces, cracked and patched by melted matter; on the contrary, it has been formed, and is still controlled, by a sublime law of action little noticed by man;—it has a beginning and an ending, like all the productions of the organic kingdom.

The south polar basin is the starting-point of the embryo of our terrestrial habitation:—the Southern Hemisphere is the Spring; the Equator is its Summer; the Northern Hemisphere its Autumn, and the North polar basin its final dissolution. Hence the study of the physical operations of nature, *i. e.* the science of Geology and Magnetism, cannot be surpassed in the magnitude of its utility, or in the sublimity of its objects. Not only is it alone second to astronomy in its scientific grandeur and deduction,—it is the stepping-stone and threshold to the temple of the *physical* sciences, and enables us to unfold some of the mysteries of the works of the Creation. The science of Geology, in combination with the surrounding controlling power which we have briefly noticed, forcibly impresses us with the fact that the human race is placed here only for a season. The world and all its productions imperceptibly pass away unobserved by the millions of animated beings who have their existence on it; we are, as it were, like parasitical insects, placed on a film which is perpetually changing, has its beginning and ending, and is equally subject to decay as ourselves. The minerals and the rocks, the rivers and the seas, the islands and the continents, with their vegetable and animal covering, are perpetually changing, leaving but faint traces of their relics behind. There is no standing still, and no resting place in the annals of the world. Generation after generation, like the shadow on the dial, pass away, and all are continually merging into eternity, according to the will and sublime laws of our Maker.

ON THE CONNEXION
OF
GEOLOGY
WITH
TERRESTRIAL MAGNETISM.

CHAPTER I.

ON THE POLARITY OF MATTER UNDER THE INFLUENCE OF THE EARTH'S MAGNETISM.

UNTIL very lately the term Magnetism was considered as applying solely to magnetic needles, bars, horse-shoe magnets, and various steel toys, which have been looked on by the world as possessing some singular inherent active principle, and not that their movements depended on the effect of an universal external power, to whose influence they had been made sensitive.

It is proved by numerous experiments that we are always enveloped in this great polar force: the most impermeable envelopic substance we can employ, and the most perfect air-pump to exhaust, cannot extract nor weaken its powers. Its directive polar force, attractive power, and effect on matter to crystallize, are equally strong under an exhausting receiver; be that in the air above, in the rocks below, or in the depths of the ocean.

This subtile power permeates all matter, causing a never-ending process of activity, both chemical and mechanical, beneath the scene of life; giving form and internal structure to the crystalline film on which we have an existence, and is the most important agent in the general œconomy of nature.

This great prime mover is always present; has been, and still is, our unerring guide across the ocean, amidst cloudy skies, or in the darkest nights on every spot of the globe; and is also the faithful guide of the miner in his subterranean explorations, and the most rapid agent of intercourse between distant towns. It is silently working within and without, perpetually forming, moving and modifying our terrestrial habitation, and rendering it suitable to our wants during all ages of transformation, and constantly providing stores of mineral wealth for successive generations.

It has been long known that if a magnetic bar be supported in such a manner as to have entire freedom of motion in a horizontal plane, it will, after a few oscillations, finally settle in a position directed more or less north and south. If disturbed from this situation, and placed in any other direction, it will, as soon as it is again at liberty to move, resume its former position. The two ends are called its Poles; the one which turns to the north being distinguished as the *north,* and the other as the *south* pole. The tendency of the magnet to assume the above described position is called its polarity; on this property is founded the mariner's compass. When we reflect on the great benefit mankind has derived from the polarity alone of magnetism, and which has so much contributed to the exploration of distant regions and to the advancement of the civilization of the human race, it must necessarily create a desire to learn something more of its general character.

It was considered for a long time that the only substance susceptible of polarity was iron and its compounds, but subsequent discoveries have proved that there is no substance but which, under suitable circumstances, is capable of exhibiting unequivocal signs of the magnetic influence, *i. e.* radial attraction, and the usual polar phænomena; and this not only in solid matter, but also in oxygen and carbonic acid gases.

In order to prove that the polarity of matter is merely the effect of the earth's magnetism, let an ordinary steel bar be buried in the ground in a north and south direction for a few months, it will be found that the bar if taken up and thrown into a trough of mercury will gradually place itself, if left undisturbed, in the exact position end for end as it previously occupied. If the same bar be placed again in the earth for a given period in a reversed direction, it would, when replaced on the mercury or delicately suspended, maintain this reversed position, showing most distinctly that its polarity depended on the direction in which it was rendered sensible to its influence when in the ground.

This effect is not confined to steel bars; any rock of the primary series, but more especially the ferruginous, if cut from the parent rock *in situ,* and suspended or floated, would take the exact position it occupied in nature; be the piece of rock an inch, a foot, a yard or a mile, the effect would be the same. Consequently, if an island, or even a continent, could be placed raft-like to float on the ocean, it would take a direction corresponding to the one it originally occupied, as the polar influence on the rocks is the same, individually and collectively.

The crystalline rocks constituting the solid surface of the globe are all more or less magnetic. The mountain of Regelberg in Germany, which consists of serpentine, is highly magnetic; its south side attracts the north pole, and its north side the south pole of a magnet.

Indeed it is well known, although not always duly considered, that the magnets were originally cut and made out of a rock called a *loadstone.* The polarity of masses of rocks have been observed in every part of the world—in the straits of Magellan, along the whole range of the Andes, in the isthmus of Panama, Mexico, the Rocky Mountains in North America, the Arctic regions, Scotland, and in various parts of the continents of Europe and Asia.

Plates IV. and V. show the average direction of the position of the magnetic needles in different parts of the globe. On reference to the Plates, it will be observed, that notwithstanding the numerous external disturbing causes such delicate needles must be subject to, they nevertheless preserve a remarkable degree of uniformity from pole to pole. The western deflection appears to predominate, the apparent cause of which will be discussed in another chapter.

These lines, which are commonly called magnetic meridians, are perpetually varying; not only from general causes, but from local effects and configurations of the dry lands; and are differing in the angle of variation even in the same meridian, being easterly in one place and westerly in another.

The name *magnetic meridians* has been applied to those lines formed by the position of the magnetic needles as described in the Plates. A line drawn at a right angle to them near the equator is called the magnetic equator, and to such a line a much greater importance has been attached than it deserves. In fact it is difficult to conceive what a line drawn across an undulating linear current can have to do with the question.

Surveys made solely by compass and without the usual checks for corrections for magnetic variations, cannot fail to produce great confusion in the boundary lines between different properties, or in carrying on new works in old mines from lines laid down in old maps.

I remember a case in point abroad where the variations had increased about 2° since the old survey and map had been made, and where certain new communications were required, which, had they been made by the compass and the old mapping, would have led to a very expensive error. This was prevented by my taking timely observations. Numerous properties as well as mines would be brought into endless litigation by the continual variation in the direction of the magnetic needle if places were constantly laid down and measured from the local meridian of the needle instead of the true.

The direction of the magnetic needle in England about 250 years ago was 11° east of north, it is now about 24° west of north; it is constantly undergoing a slow oscillation.

The following Table shows the change which has taken place in London from the years 1576 to 1850:—

Years.	Variations.	Years.	Variations.
1576	11° 15′ 0″ Easterly.	1774	22° 20′ 0″ Westerly.
1580	11 17 0 ,,	1778	22 11 0 ,,
1622	6 12 0 ,,	1790	23 39 0 ,,
1634	4 5 0 ,,	1800	24 36 0 ,,
1657	No Variation.	1806	24 8 0 ,,
1662		1813	24 20 17 ,,
1666	0 34 0 Westerly.	1815	27 27 18 ,,
1670	2 6 0 ,,	1816	24 17 9 ,,
1672	2 30 0 ,,	1820	24 11 7 ,,
1700	9 40 0 ,,	1823	24 9 40 ,,
1720	13 0 0 ,,	1831	24 0 0 ,,
1740	16 10 0 ,,	1840	24 0 0 ,,
1760	19 30 0 ,,	1850	24 0 0 ,,

Besides the progressive changes in the direction of the needles, there are annual or periodical movements and daily oscillations constantly taking place in all parts where magnetic observations have been made. The dip of the needle, like the horizontal variation, has different values in different parts of the globe; on an average being horizontal near the equator, and perpendicular to the horizon at the poles. Hence, if a magnetic needle were to be balanced at the equator, it would be found to decline from its horizon as we proceed from thence towards the poles: its average position forms a curve, called the 'Magnetic Curve,' from pole to pole, as shown in Plate IV.

On looking at the general direction of the magnetic curves and the magnetic meridians, we observe that they tend to converge at the poles, notwithstanding their deflections and undulations from various local disturbances. Numerous fruitless investigations have been made with the view of ascertaining the position of the magnetic poles, as if these were *mathematical points*.

Any person who has had experience with the action of fluids, whether water, air or electric, converging towards or diverging from a central passage, must know that they cannot be forced into a *mathematical point*; there must be a limit to their compression or density; nor can it be expected that every individual current should retain its exact radial course towards the focus, and much less when diverging from it. Hence from analogy and observations, the narrowest limits that we can assign to the polar axis to which the magnetic currents converge and diverge are, perhaps, the areas bounded by the arctic and antarctic circles.

By taking these extensive spaces for the magnetic poles, we shall be relieved from entering into the useless and endless inquiries respecting late discoveries, and formulas which have been established or founded on them. The question is rendered simple, not requiring formulæ which profess great accuracy in points where the data of observation must be very uncertain.

Numerous observations have been made in the equatorial regions, indicating both east and west variations in the *same meridian* of only a few leagues in extent, proving that the direction of the needle does not necessarily point towards the centre of convergence of the currents, but in the direction of the local deflection. The position of the needles may be compared to what they are when suspended over a long undulating telegraph wire. They do not point in the direction of the main current, but are all deflected proportionally to the intensity of the electricity passing through the wire and the angle of the bends. The local disturbing force being a variable quantity subject to perpetual fluctuations, it follows as a consequence, that the variations of the direction must be uncertain, and therefore not within the power of any formulæ to know their periodical amount.

In the above our observations have been principally confined to the direction of the needles; but as it is proved that the needles only indicate the presence of an universal power, and since we cannot withhold our conviction, after tracing the curves which the needles form within, on, and above the earth, that the globe is a magnet, *i.e.* that its axis is magnetic, and according to the law of magnetism, founded by direct experiment, the *north* end is the attractive and the *south* end is the repulsive, or in plainer language, that the magnetic currents move towards the north, then absorbed by the axis, issue out again from the south pole and encircle the globe to complete their circuit (as indicated by the direction of the needles, and illustrated by the arrows in the following sketch).

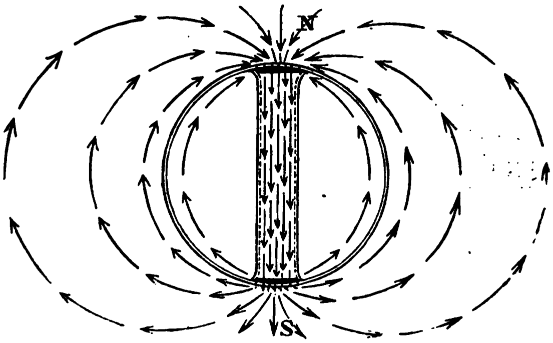

Fig. 1.

If the earth then be a magnet, its magnetism must produce the effects observed; if it be not a magnet, it possesses at all events a property identical in its results to one; therefore all we require in our investigations is the knowledge of the law of these actions, as the mere *name* of the primary cause of this spherical principle of activity cannot have a material influence with our researches. If we call it *gravitation*, we must add to it a property which was not applied to it before, viz. polarity,—call it *magnetism*, and the term embraces all we require in the various physical operations incessantly going on within, and on the surface of our terraqueous globe*.

Let us suppose a bar, having been made magnetic, to be placed in the axis of an artificial globe; if iron filings be strewed carefully over it, the filings would become magnetic, and arrange themselves in curves like the magnetic needles on our globe, as shown in Plate I.

The small magnetic ingredients do not converge to one mathematical point at each end of the bar, but to a space equal to the transverse section of the axis; and if this effect is produced by a current of subtile fluid, which may be conceived to emanate from one pole and to enter in at the other, permeating the bar, and again issuing from its former outlet, as exhibited by the arrows in the above diagram, it is reasonable to suppose that the fluid will not be compressed more than the transverse size of the bar will require. Taking this simple principle of action as a guide, with its various consequences under different circumstances, we shall perceive that we not only account for the various phænomena of geology, but, in a word, *all* phænomena connected with terrestrial physics; and that we are enabled also to reason from the known to the unknown, and actually to predict facts before trial, not merely to satisfy curiosity, but questions of practical utility. Indeed, theories are not worthy of attention unless they can be fairly demonstrated, and rendered practically useful, and elucidated in simple and clear language.

To proceed with our subject, let us place the above bar on a centre, or to float on water, we shall find it will take a meridional position; it is therefore manifest, that by some internal action the iron bar is rendered susceptible of allowing the polar stream to pass through it *only in one direction*, viz. *from the south to the north end of the bar.* If we cut the bar into several pieces, what would be the result, supposing that by so doing we do not injure its magnetic susceptibility? Might we not reasonably expect the same phænomena in the separate parts as when entire, viz. that the polar action would still preserve its definite direction through the separate pieces as when entire? Such is the fact; every portion of the fractured magnet is a magnet perfect in itself, *i. e.* each has a north and a south end corresponding to their united position. Similar effects ensue from the subdivision of one of these fragments into any number, however great; and if reunited, by placing them together again in the same position, the result would be the same; that such would be the case is very evident, as the separation of the magnetic bar, provided it be effected without injuring its magnetic properties, only diminishes the length of the pores, not changing or altering the natural direction imparted to it originally.

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* It has been supposed by many that the terms positive and negative, and attraction and repulsion, represent two distinct qualities or principles of action. To avoid such erroneous notions influencing the mind of the reader in the perusal of these pages, or at all events to prevent misconceptions in our present inquiry, it must be distinctly understood that the opposite poles are only considered as the *absorbing* and *evolving* points of activity through which the circulating power permeates, and not distinct qualities.

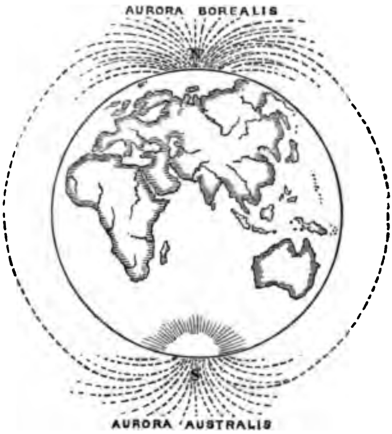
This reasoning will show that two similar poles must repel one another, and that two dissimilar poles attract each other, owing to the tendency of the circulating currents to obtain a free passage, each being deflected according to the quantities of their æthereal volumes of activity and respective amounts of resistance. The intensity of the action must be as the density; and if we assume that the whole of the circulating currents round the magnet, within a certain limit, are converged into the polar focus, their intensity must increase towards that point inversely as the square of the distance; like any other fluid, air, water, or steam, which may converge to, or diverge from, a central passage. Consequently we can determine the resultants of the forces which may act upon a magnetic needle when its centre is situated in different directions relatively to the axis of another magnet; and what will be its movements, and what its final position of equilibrium. This is an amusing and very instructive mode of experimenting, and may be elegantly explained on a table, with a series of pocket compasses and bar magnets.

In placing needles round an artificial globe, we find them arranging themselves in the exact order as seen on the terrestrial globe, both as to dip and direction; but as there is nothing to disturb them in the former, their positions in the curves of convergence are uniform, and equal to the transverse area of the magnetic axis at both ends.

We find in measuring the force along the magnetic curves, that it varies inversely as the distance: allowing for the influence of the earth's magnetism, and tracing the effects in a horizontal plane, we obtain the following law, viz. *that the force varies inversely as the square of the distance from the surface of the ball in the equatorial plane, and also in the meridian from the poles towards the equator*; being the necessary consequence of the expansion and compression of the magnetic power: this is precisely the law of what is called gravitation. The meridional variation towards the poles of the earth has been hitherto ascribed to the effect of a centrifugal force produced by the earth's rotation, and is also considered as the cause of the earth being an oblate spheroid. A globe constituted under similar conditions as our earth is, with its enveloping fluids placed under the influence of centripetal and centrifugal forces, according to the well-known laws of physics, could not produce the observed figure, much less the variation of attraction towards the poles. Such effects as those ascribed to rotation are not known at the equator. As the surrounding atmosphere rolls with it, the surface cannot be exposed to rotatory effects. Its magnetism alone, without rotation, must necessarily compress the poles, and also cause the inverse law of intensity in the enveloping fluids.

In order to show further that there is no necessity for a rotatory or centrifugal force to cause or at least to preserve an oblate spheroid in a similar body, let us take the moon as an example. She is an oblate spheroid, yet she does not rotate, *i. e. on an axis situated within her body*, because she always presents the same face towards the earth. Magnetism alone forms a spheroid by the variable intensity of the currents, and this effect is observed from the dew drop to the magnitude of the celestial globe. Methods have been devised for measuring the attractive force of the whole globe, compared to that of some of its parts; according to which it has been inferred that the density and specific gravity of the globe is nearly five times as great as that of water. Calculations of this kind are liable to error, inasmuch as the attraction of a *hollow* shell is equal to a *solid* one.

If this be the primary agent by which all the substances of our globe are governed, we ought to be able to trace its effects according to the above principles of action, viz. circulating from south to north over the surface of our earth, with a force varying inversely as the square of the distance from the respective centres. Commencing with the *atmosphere,*—We see the luminous appearances connected with the poles of our earth, called aurora borealis and australis, corresponding to the curves of convergence towards the poles, as shown in the following sketch.



When these luminous phænomena display unusual brightness and activity, the magnetic needle is found very fluctuating, both in dip and direction, the mercury in the barometer being often subject to similar action. This coincidence of the movements indicates that they are produced by the same cause, viz. the disturbance of the equilibrium of the tension of the enveloping magnetic power.

The horary variations of the barometer within the tropics present two maxima and two minima—the former at 11 A.M. and about the same time at night, and the latter, 5 P.M., and a corresponding period in the morning, as will be observed in perusing the following tables *.

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* I am indebted to Mr. Albert Dumaresq, my assistant, for his indefatigable assistance in registering these observations day and night, during a portion of my last researches in Equatorial America.

BAROMETRICAL OBSERVATIONS.

SANTA MARTA.

Latitude 11° 14′ N. Long. 74° 14′. 13 ft. above the level of the sea.

844.	Barometer.					Remarks.
	Hour.	Height in inch.	Temp. Mer.	Temp. Air.	☽'s Age.	
ay 10.	12 a.m.	29·938	86·50	85·50	☾	Dry and windy*.
	3 p.m.	29·920	84·50	84·0	...	Showery.
	9 p.m.	29·960	82·50	82·50	...	Cloudy.
	6 a.m.	29·918	81·50	81·50	...	Cloudy.
	9 a.m.	30·280	82·00	82·50	...	Cloudy and showery.
11.	12 a.m.	29·980	83·00	82·00	...	Showery.
	3 p.m.	29·932	81·00	81·00	...	Thunder and { temp. of rain 80°.
	6 p.m.	29·932	81·50	81·20	...	heavy rain { temp. of air 82°.
	9 p.m.	29·966	81·00	81·00	...	Very wet.
	6 a.m.	29·980	81·00	80·50	...	Cloudy.
	9 a.m.	29·980	81·00	81·00	...	Heavy rain.
12.	12 a.m.	29·958	82·20	82·00	...	Cloudy.
	3 p.m.	29·908	82·00	81·50	...	Cloudy and showery.
	6 p.m.	29·900	80·50	80·50	...	Showery.
	9 p.m.	29·940	81·50	81·50		
	12 p.m.	29·924	81·00	81·00		
13.	3 a.m.	29·900	81·00	80·50		
	6 a.m.	29·944	81·00	81·00	...	Fine clear day. [when high tide.
	9 a.m.	29·970	82·00	82·00	...	High water; tide about 18 inches
	12 a.m.	29·942	84·00	83·50	...	Dry and windy.
	3 p.m.	29·888	82·00	81·50	...	Heavy showers and thunder.
	6 p.m.	29·996	81·50	81·50	...	Thundering.
	9 p.m.	29·944	81·00	81·50	...	Heavy rains, thunder, windy.
14.	6 a.m.	29·910	81·00	81·00	...	Cloudy.
	9 a.m.	29·994	81·00	81·00	...	Clearing up a little.
	12 a.m.	29·988	83·00	83·00	...	Dry.
	3 p.m.	29·870	82·50	82·20	...	Cloudy, but dry.
	6 p.m.	29·870	82·20	82·20	...	Windy.
15.	3 a.m.	29·924	81·00	81·50	...	Cloudy.
	6 a.m.	30·000	81·00	81·00	...	Dark clouds, thunder and lightning.
	12 a.m.	30·036	79·50	79·50	...	Heavy showers and thunder.
	3 p.m.	29·950	78·50	78·50	...	Showery and dark clouds.

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* Temperature of the Carribean Sea:—

	°
Surface	83
240 fathoms deep	48
386 " "	43
450 " "	42
500 " "	41

Table (continued).

1844.	Barometer.					Remarks.
	Hour.	Height in inch.	Temp. Mer.	Temp. Air.	☽'s Age.	
May 15.	6 p.m.	29·974	78·00	78·00	...	Dark cloudy evening.
	9 p.m.	30·012	78·00	78·50	...	Very wet.
16.	6 a.m.	30·000	78·50	78·50	...	Fine morning, but cloudy.
	9 a.m.	30·042	79·00	79·00	...	Fine morning, but cloudy.
	12 a.m.	29·986	81·50	81·75	...	Dry and hot.
	3 p.m.	29·934	82·00	82·00	...	Dry and hot.
	6 p.m.	29·930	83·00	82·00	...	Clear sky*.
17.	3 a.m.	29·944	80·50	80·50	●	
	6 a.m.	29·970	80·20	80·50	...	Fine morning.
	9 a.m.	30·000	81·75	81·75	...	Fine morning.
	3 p.m.	29·936	85·20	85·00	...	Clear sky.
SANTA ANA. Latitude 5° 10′ N. Long. 75° 0′ W. 3000 ft. above the level of the sea.						
Sept. 2.	3 p.m.	27·600	77·00	77·00		
3.	9 a.m.	27·150	75·50	75·50		
4.	5 p.m.	27·380	77·00	77·50	☾	
5.	8 a.m.	27·162	74·50	74·50		
	3 p.m.	27·260	79·00	79·00		
	9 p.m.	27·124	76·50	76·50	...	Cloudy.
6.	12 a.m.	27·132	74·00	74·00	...	Wet morning.
	6 p.m.	27·180				
	10 p.m.	27·150	....	74·50	...	Stationary about 11, and sinking after 11, noon.
21.	10 a.m.	27·234	72·50	72·50	...	Very foggy; damp.
	11¼ a.m.	27·154	72·00	71·50	...	Very foggy; damp; very windy.
	12 a.m.	27·130	72·50	72·50	...	Clearing up; very windy.
	1½ p.m.	27·114	74·75	74·00	...	Clearing up; very windy.
	3½ p.m.	27·440	74·00	74·00		
	9½ p.m.	27·138	73·00	73·00	...	Cloudy and calm.
	12 p.m.	27·146	73·00	73·00	...	Cloudy and calm.
22.	8½ a.m.	27·146	72·00	72·00		
	2 p.m.	27·540	75·00	75·00	...	Cloudy and mild.
	3 p.m.	27·500	....	....	...	Shock of an earthquake.
	11 p.m.	27·130	74·50	73·00		
23.	9 a.m.	27·170	71·00	72·00	...	Cloudy and rainy.

	°	′
* Declination north at 6 ..	19	17
Latitude	11	14
	8	3
Azimuth from mag. meridian	283	35
270°+8° 3′=	278	03
Mag. var. E.	5	32

Table (continued).

344.	Barometer.					Remarks.
	Hour.	Height in inch.	Temp. Mer.	Temp. Air.	☽'s Age.	
			°	°		
t. 23.	2 p.m.	27·116				
	9 p.m.	27·154	73·50	74·00		
24.	3½ p.m.	27·180	75·50	75·50	...	Cloudy and damp.
25.	7 a.m.	27·146	73·00	73·50	...	Cloudy and damp.
	9½ a.m.	27·218	73·00	73·00	...	Cloudy.
	2 p.m.	27·110	75·00	75·50	...	Cloudy.
	3 p.m.	27·680	75·50	76·00	...	Clearing.
	7 p.m.	27·110	74·50	74·50	...	Cloudy.
	10 p.m.	27·170	73·50	74·00	○	Thunder and wind.
26.	7½ a.m.	27·170	76·00	76·00	...	Fine morning.
	12 a.m.	27·168	75·50	75·50	...	Fine, but rather cloudy.
28.	9½ a.m.	27·220	72·50	72·50	...	Foggy and rainy.
	1½ p.m.	27·144	74·50	74·50	...	Cloudy.
	4 p.m.	27·840	75·00	75·00	...	Cloudy.
	10 p.m.	27·176	74·00	74·50	...	Showery.
29.	8½ a.m.	27·250	74·00	72·50	...	Thick, wet and foggy.
	2 p.m.	27·134	73·00	73·00	...	Clearing up.
	9½ p.m.	27·196	72·50	72·50	...	Cloudy.
30.	7 a.m.	27·214	72·50	72·50	...	Mild morning.
	9½ a.m.	27·250	72·00	73·00	...	Cloudy.
	1 p.m.	27·188	74·00	74·00		
	3½ p.m.	27·134	75·00	75·00	..	A little cloudy.
	4 p.m.	27·124	75·00	75·50	...	A little cloudy.
	5 p.m.	27·124	75·00	74·50	...	Clear sky.
	7½ p.m.	27·124	74·00	73·50	...	Clear sky.
	9½ p.m.	27·184	74·00	73·50	...	Clear night.
	10½ p.m.	27·184	73·50	73·50	...	Cloudy.
	11½ p.m.	27·184	74·00	74·00		
ct. 1.	6½ a.m.	27·180	73·00	72·50	...	Fine morning.
	1½ p.m.	27·170	75·00	75·50	...	Light clouds.
	5 p.m.	27·920	75·50	75·00	...	Light clouds.
	6 p.m.	27·920	75·00	75·00	...	Light clouds.
	8 p.m.	27·138	74·50	74·50	...	Light clouds.
	10½ p.m.	27·174	74·50	74·50	...	Light clouds.
	12 p.m.	27·176	74·00	74·00	...	Light clouds.
2.	7 a.m.	27·176	72·00	72·50	...	Wet morning.
	10 a.m.	27·200	72·00	72·00	...	Low clouds.
	8 p.m.	27·120	74·00	74·00	...	Stormy night; thunder and lightning.
	12 p.m.	27·150	73·00	73·00		
3.	11½ p.m.	27·180	74·00	74·00		
4.	5 p.m.	27·260	74·00	74·00	☾	
5.	9 a.m.	27·234	73·00	73·00	...	Heavy rain.
6.	8 a.m.	27·268	71·50	71·00	...	Heavy rain.
8.	7½ a.m.	27·258	71·00	71·00	...	Light rain.
11.	11 p.m.	......	...	...	...	Shock of an earthquake.
12.	7½ a.m.	27·210	72·00	71·¼	...	Low clouds.

MARMATO.

Latitude 5° 24′ N. Long. 75° 50′ W. 4258 ft. above the level of the sea.

1845.	Barometer.					Remarks.
	Hour.	Height in inch.	Temp. Mer.	Temp. Air.	☽'s Age.	
			°	°		
Feb. 3.	12 a.m.	25·628	72½	72¾	26	Dry and windy.
	7½ p.m.	25·600	74	74¼	...	Fine night.
4.	7 a.m.	25·656	70	70	27	Fine morning.
5.	8 a.m.	25·700	69½	69	28	Cloudy damp morning and wet night.
	10½ p.m.	25·688	71	70	...	Damp night and clear sky.
6.	7½ a.m.	25·688	67	67	●	Foggy morning.
	11 p.m.	25·600	71	70½	...	Fine starlight night.
7.	7½ a.m.	25·656	68	68	...	Dry and windy.
	6½ p.m.	25·636	73	73¾	...	Fine, but cloudy; a slight shower this evening.
	9 p.m.	25·700	73	72½	...	Cloudy.
8.	7½ a.m.	25·714	69	69½	...	Wet morning.
	5½ p.m.	25·600	73½	73	...	Fine, but cloudy evening.
	11½ p.m.	25·650	70½	70	...	Fine starlight night.
9.	8½ a.m.	25·684	67	67½	...	Fine morning.
	12 a.m.	25·658	72½	72½	...	Fine day, windy.
	2½ p.m.	25·600	73	72½	...	Fine day, windy.
	9½ p.m.	25·670	72	71½	...	Starlight night.
10.	7½ a.m.	25·686	68	68	...	Fine morning.
	12 a.m.	25·660	71½	71½	...	Fine morning.
	10½ p.m.	25·684	72	71	...	Fine starlight night.
11.	12 a.m.	25·660	70	70½	...	Fine day.
	4½ p.m.	25·620	72½	72½	...	Cloudy evening.
	11 p.m.	25·716	71½	71	...	Starlight night, but with some clouds.
	11¾ p.m.	25·730	71	70½	...	Heavy shower, with sharp claps of thunder and lightning.
12.	7 a.m.	25·730	69	68½	...	Damp and foggy.
	2 p.m.	25·684	72	71½	...	Light showers.
	10 p.m.	25·734	69	69	...	Starlight night.
13.	7½ a.m.	25·770	66	66	...	Fine, but low clouds.
	12 p.m.	25·740	70	70	☽	Fine day, light clouds.
April 9.	6 a.m.	25·586	73½	73½	...	Fine sunny morning.
	10 a.m.	25·712	74	74	...	Fine, but little cloudy.
	12½ a.m.	25·660	74½	74½	...	Fine, but little cloudy.
	2½ p.m.	25·636	74½	74½	3	Low clouds, thundering at a distance, and slight rain.
	10½ p.m.	25·716	73½	73½	...	Stormy, thunder, lightning, and rain.
10.	7½ a.m.	25·720	71	71	...	Fine morning.
	10 a.m.	25·716	71½	71½		
	12 a.m.	25·650	73	73	4	Hot, but cloudy.
	4 p.m.	25·608	74	74	...	Showery, thundering in the neighbourhood.
	7 p.m.	25·620	72½	72½	...	Cloudy.
	10 p.m.	25·680	72	72	...	Cloudy, lightning southward.

The regularity of this rise and fall of the mercury within the tropics below the elevation of 3000 feet above the level of the sea, is seldom disturbed by the change of weather; and we may, with a good barometer, such as I had, infer the hour of the day from the height of the column of mercury.

We observe the same regularity in the variations of the magnetic needle. From 8 A.M. the needle is gradually deflected until 2 P.M., at which period, during the strongest heat of the sun, the needle occupies the maximum westerly variation, and returns to the eastern angle of the arc in the coolest part of the day. This variation is like the oscillations of the mercury, viz. greater near the polar regions than at the equator.

The recent brilliant discoveries of Professor Faraday have established the intimate relations between the electric tension of the atmosphere and the electro-magnetic condition of the earth; and that this influence is as much apparent in the gases oxygen and nitrogen, as in their combination with other substances.

The aurora is the effect of polar activity, excited to the production of a luminous phænomenon; an activity which often manifests itself from pole to pole in meridional bands of white clouds*. The evolution of polar lights may be the indication of the restoration of the equilibrium in the distribution of the aërial electro-magnetic force.

On the days when the southern aurora takes place, the same phænomenon is observed in the north, and therefore simultaneously produced like the lights produced by an artificial magnet.

If this permeating power emanates from the south pole and proceeds to the north, thence returning into the axis to complete its circuit of activity, we should expect a difference of appearances in the south aurora as compared with the north: the former rises from an aqueous element, whilst the latter descends from the aërial towards the polar axis. We find the southern aurora, generally speaking, presenting the appearance of long columns of clear white light, shooting up from the horizon to the sky; the figure being in every respect similar to the northern lights, with the exception of their being of a whitish colour. The northern lights assume more fiery tints of purple hue.

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* This phænomenon I have frequently witnessed in the Atlantic and Pacific oceans.

The saturated hydrogenous character of the aërial polar force coming from the south pole, will account for the observed peculiarity of the southern hemisphere in its temperature, moisture, rains, the growth of gigantic vegetation, &c., as compared with the northern hemisphere.

Hence the great ocean of air which envelopes the planet we inhabit, to which we are every instant beholden for supplying us with the elements of vitality, is permeated and bound into a sphere by this magnetic power. Whatever substances may be decomposed and converted into gases and rise to the atmosphere, are again returned into the earth. Nothing can escape or be destroyed: they are made to combine and continue active agents in the business of the world, and main support of vegetable and animal life, and are still susceptible of running again and again the same round as circumstances of terrestrial operations may determine.

CHAPTER II.

THE IDENTITY OF THE PRINCIPLE OF MAGNETIC AND GALVANIC FORCES.

ALTHOUGH the sciences of magnetism, galvanism and electricity have been effectually blended, and proved by various experiments to be the effects of one primary cause, the direction of the magnetic currents compared with galvanism is considered different, *i.e.* that the magnetic currents move at right angles to those of galvanism. This idea has arisen from the effects of the *spiral* course in which the external current that envelopes the connecting wire of a battery moves towards the negative plate. For instance, if the connecting wire of a battery, or the wire of an electric telegraph, be placed in the meridian, having its negative plate attached to the north end and the positive plate to the south, the external current enveloping the wire will move northward towards the negative plate in a spiral form. On the upper side of the wire it moves towards the north-west, and on the under side towards the north-east; on the western side it moves downwards, and on the eastern side upwards. This spiral nature of the current produces motion in a circular direction round the wire, which is exhibited in various electro-magnetic machines. The direction of the external current is thrown into a spiral course, proportionably to the intensity of the force and resisting power of the internal streams. Supposing the intensity of the current causes the needle when held above the wire to deviate thirty degrees to the west, in placing it underneath the wire it will deviate thirty degrees to the east; taking the mean of the two, we find that the direction corresponds to that of the wire.

It is a singular fact, that the creeping or entwining plant, if in the neighbourhood of a trunk of a tree, will approach and grow round it in one definite and constant spiral direction; yet both possess the same directive principle of ascending force, as shown in the following diagram*, fig. 1.

Fig. 1.

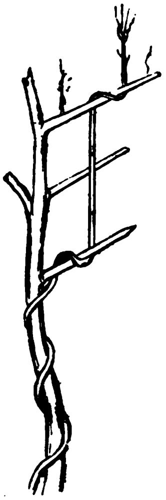
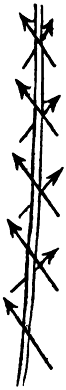


Fig. 2.



The magnetic needle in the presence of the galvanic wire exhibits the same spiral phænomenon, as illustrated by fig. 2.

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* This interesting subject, connected with the physiology of vegetation, will be entered into in another chapter.

All known forces, emanating from a certain point and exerted upon another point, act in the direction of the line joining these two points. Such is the effect of a stream of-water on a substance exposed to its action, and on a vane by the wind, which always points in the direction of the current. The same law applies to electric and magnetic actions, in all the cases that belong exclusively to the one or to the other, and are only deflected by their mutual resistances.

When two conducting wires, bent into helices, act upon one another, which they do in a manner that imitates exactly the mutual effect of two magnets, it is called electrical, and is exerted in the lines of direction that join the acting points. The same is the case with two magnets. When the latter is exposed to the influence of the former, it causes the spiral current above alluded to. All fluids, when forced through tubes by a great force, have a tendency to move in a spiral direction, as commonly observed in a funnel, water falling through pipes, or a stream of air forced through a tube. However, if we take the mean of the direction of the spiral, we find that it corresponds to the direction of the wire; therefore we may consider that the magnetic needle, enveloped as it is in the great terrestrial magnetic fluid, is only slightly deflected westward from the direction of the subterranean stream, but yet indicates the direction of the external currents.

In the battery we find that the currents of hydrogen move from the zinc to the silver plate, along or through the connecting wire. We find by experiments that the south pole of a magnet has a greater affinity for oxygen than the north pole. The difference in the oxidation of the south pole, compared with the north, is easily proved by various simple methods. All that is required is to place the ends of a magnet in water, and allow it to remain undisturbed for several days, and the fact is soon proved. A very powerful horse-shoe magnet will decompose water, and the oxidation will be observed to go on at the south pole, and the evolution of the hydrogen at the north pole*: hence it is manifest that the currents move from the south pole to the north pole of the needle: the magnet possesses the property of *filtering*, as it were, *the oxygen from the polar stream.*

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* These poles are named according to their position, and contrary to the great terrestrial poles, inasmuch as the north pole of the magnet is the evolving, whilst that of the earth is the absorbing pole.

Ritter asserted that a needle, composed of silver and zinc, had arranged itself in the magnetic meridian, *i.e.* the zinc towards the south and the silver towards the north, and was slightly attracted and repelled by the poles of the magnet: to effect this the air must be very moist. Generally speaking, such needles can only act when immersed in liquid. In the air the needle must be composed of such substances as will be capable of decomposing that element to indicate polarity. It is a singular fact that those rocks which contain manganese combined with iron ore are the most magnetic, and will preserve longer their polarity.

CHAPTER III.

ON THE REDUCTION AND FORMATION OF METALS BY ELECTRO-MAGNETISM.

When metals are observed in rocks and in veins, which is of common occurrence in mineral districts, persons are too apt to think that such metallic substances have been produced by intense heat, similar to that applied in smelting works. Such an idea arises from the habit of our looking at metals as the production of our ordinary artificial process of reducing minerals, and not to any cause that can be assigned for this being the only mode of their formation.

When we make a casting of any metal, even the most fusible, we find great difficulty in getting it to take the minute impression of the mould, owing to the great heat necessary to give the metal the required looseness and pliancy. The liquid metal has a considerable amount of cohesion, which tends to make it form into large drops, like that observed in quicksilver; which drops cannot be reduced without intense heat to destroy its cohesion. Besides, the substance which forms the mould must not only be capable of enduring a very high temperature, but sufficiently porous to allow the air to escape, otherwise it cannot produce a smooth face.

The native metals which are found in mineral deposits are often enclosed in quartz; but on whatever substances they may be, they present the exact impression, even the most minute cracks or striæ of the mould. Nor are the substances on which such metals are produced always confined to those that resist intense heat; on the contrary, native copper and silver have been found deposited on timber, and decayed leaves in old mines; and this during their immersion in water. It is therefore very evident that the ordinary process by fusion is not capable of fulfilling the above conditions of the metals in the mines: but it is identical with those formed in the humid way by electro-magnetic action.

In speaking of metals, we should not forget that a great number of them are found not as solids, but in solution in the rocks. Indeed there is no rock *in situ* that is not found more or less saturated with mineral waters.

Iron is abundant almost in all mineral waters.

Copper is found in solution in all the copper mines in Europe and America; and a large proportion of copper is obtained by the introduction of iron to precipitate the metal from its solvent in Anglesea, Spain, New Brunswick, &c.

All metals are capable of remaining in solution as well as in their solid state.

Platinum remains in solution with one part of nitric to two of muriatic acid.

Gold is soluble in nitro-muriatic acid; and held in solution, also in caustic alkali.

Silver is soluble in nitric acid, and in sulphate of iron.

Nickel dissolves in nitric acid, and alkaline menstruum.

Zinc, *Lead*, and in a word, all metals, are susceptible of remaining in solution as well as in a solid state; therefore we should not consider that the metals must necessarily be solid in their original state. The oxides of metals and of cobalt dissolve in large quantities in caustic potash, and may be diluted with water, without a separation of the oxides. Caustic potash is also the natural menstruum of siliceous substances. Indeed there is some difficulty in preserving some metals, especially iron and zinc, in their metallic state, in consequence of their great affinity for oxygen; and those metals only which possess but little affinity for this element, such as platinum, gold, silver and copper, are found precipitated and preserved amongst the debris of rocks in their metallic state.

When we subject any metallic solution to the action of the magnetic current, the metal will be reduced, in different states, according to the strength of the solution and the intensity of the force employed.

In order to ascertain experimentally what are the circumstances which tend to produce these conditions, we have only to procure a galvanic battery and connect it with two platinum poles, which we place in a vessel to serve as the precipitating trough. In this trough we place a saturated solution of a metallic salt—for instance, copper—when on examination, if the battery possess but feeble power, we shall find that crystalline copper will be deposited; if, however, we dilute this solution with twice, thrice, or four times its bulk of water, the metallic deposit will assume a very different aspect: it will then be aggregated in a flexible state, or a reguline deposit. If we now dilute this same solution to an infinitely greater extent, the metal will still be reduced, but in the form of a very fine black powder.

Almost all metallic solutions may be substituted for that of the sulphate of copper, and the experiment will show nearly the same result, namely, that the strength of the metallic solution influences the nature of the deposit.

If we examine the converse of the experiment, and take a solution of sulphate of copper, and use successively, first, one very small battery, then two or three batteries arranged in a series, and lastly, a very intense battery, we shall find that with this self-same solution we can obtain by these means, first, a crystalline, then a reguline, and subsequently a black deposit.

The above variable state in which minerals are deposited by the battery is of common occurrence in mineral veins; and even the same vein presents large and small crystals, and often of variable composition, within a very small compass. We also find the crystals which had formed the nucleus of one variety disappear, and the cavity left become filled with a different substance.

The application of the agency of fire to form such crystalline deposits, is totally inconsistent with the observed facts; whereas a magnetic or galvanic current passing through the solutions, is capable of imitating such productions, not only those of the mineral veins, but also of all the operations of nature disclosed by geology.

In order to understand how the metals are reduced from their solutions by the agency of a galvanic current, let us take a battery, and observe the actions going on. In placing a plate of zinc in water, and allowing it to be immersed in it for a long period, it becomes coated with an oxide; but if the water be diluted with sulphuric acid, the oxide will be dissolved, and the zinc will continue to present a clean surface to the oxygen of the water, until it is entirely dissolved, provided there be a sufficient supply of that element present.

The above chemical action is however comparatively feeble. This feebleness of action appears to arise from the want of another power to take away the hydrogen evolved during the decomposition of the water by the zinc. If we place another metal having a less affinity for oxygen than the zinc in the same vessel, and connect the two by a copper wire, the action is considerably increased, and the hydrogen evolved from the decomposition of the water is apparently conveyed from the zinc by means of the connecting wire, and finally escapes from the surface of the plate which forms the negative. And it has been experimentally proved that the greater the facilities by which the hydrogen is made to evolve from the negative plate, the greater is the action on the zinc or positive plate.

The positive plate may be considered as the fuel of the battery, and the connecting wire, with its negative plate, the flue and chimney of the battery. If we increase the draft of the chimney for the escape of the decomposed air, the greater is the supply of oxygen to the fuel; if we break the connexion between the fire and chimney by shutting the flue, we check the combustion; and such is the nature of the battery *.

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* The electric light, heat, or motive force are governed by the same principle of action, viz. for any given result produced, a given quantity of some material must be consumed, or changed, in the battery. As it is necessary to burn a certain quantity of coal to produce the required amount of steam and horse-power in a steam-engine, so it is necessary to effect a similar change in a certain quantity of the elements of a battery to produce any electro-magnetic force. According to experiments made by Mr. Hunt, a grain of zinc consumed

In order to increase the intensity of the battery Mr. Smee introduced platinized silver, which possesses the singular properties of evolving, or rather liberating the hydrogen with great facility; hence the draft is thus increased, and consequently the combustion of the zinc accelerated. The direction of its current is from the positive to the negative plate, and it is the positive plate that commences the action and causes the decomposition. The metals in solution are reduced into their metallic state in the decomposing trough of the battery on the negative plate, *i. e.* the plate which evolves the hydrogen. The hydrogen in oozing out of the negative plate seizes upon the oxygen of the oxide of copper, and forms water, whilst the metallic copper is thrown down on the plate; and as long as the strength of the metallic solution is kept up and remains in contact with the plate, the hydrogen issuing out will continue to liberate the metal from the oxygen, and the reduced mineral will present the appearance of a lateral growth from the plate, analogous to an efflorescence or radial crystallization.

Whilst the above action is going on, on the negative plate, a contrary effect is taking place on the positive. If the positive plate of the decomposing trough be copper, as is always the case in reducing copper solutions, the acidulated water in contact becomes decomposed by the oxygen uniting to the copper, the quantity of copper reduced at this plate being about equal to that formed on the opposite plate, and thus the strength of the solution is kept up, according to the system of electro-plating; the effect being due to one constant direction in which the hydrogen moves, uniting with the oxygen at one pole, and becoming liberated from it at the other.

We have already observed that the crystalline character of the reduced metal depends on the intensity of the current and the strength of the solution. If the current be very intense, causing the evolution of the hydrogen from the negative plate, it forms a fine black powder; if none evolves, the metal is generally thrown down in its crystalline state.

The quantity of electricity passing influences the state of the

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in the battery induces an electro-magnetic force capable of lifting 80 lbs. 1 foot high; whereas, in the boilers of the Cornish steam-engines one grain of coal produced steam-power capable of lifting 143 lbs. through the same space.

crystals, for there are varieties of deposit, one of which arises from a deficiency of quantity in relation to the strength of the solution; the metal is like an aggregation of sand, the particles having no cohesion or consistence. In this state the plate of metal is in the utmost state of brittleness, and this is produced by too small a quantity of electricity in a strong metallic solution. Another variety of the crystalline state of metals arises from a large quantity of electricity in relation to the size of the plate; thus, by using a very large positive pole, connected with a battery of feeble intensity, and by employing at the same time a strong solution, large crystals, possessing the utmost degree of hardness, will be thrown down. In a word, innumerable varieties may be formed by different degrees of force and solutions.

Comparing these facts with those observed in metalliferous deposits, we find a very striking coincidence; and when we apply similar laws and orders of deposition to mineral veins and crystalline rocks, the problem of their formation is easily solved without having recourse to the igneous theory. Indeed the subterranean action alone, without the aid of any artificial battery, is sufficient to produce the effects above explained, as proved by Mr. Fox some years ago.

CHAPTER IV.

ON HEAT PRODUCED BY THE ELECTRO-MAGNETIC OR GALVANIC FORCE.

THE next phænomenon which a battery displays is the power of heating substances according to the amount of current which is actually passing, and the resistance which they afford to its passage; and in this way the most infusible metals, as platinum, palladium, gold, copper, iron and steel, may be instantly melted.

Conducting liquids may be heated in a similar manner. This fact may be seen in a great variety of ways: dilute sulphuric acid may be made to boil in a siphon connecting two vessels, in which the poles of an extensive series of batteries are placed. Another mode of showing the same fact is to take a piece of string and moisten it with acid, and connect it with the poles of a series of electro-magnetic batteries, when it will begin to *smoke*, and become *charred* from the heat produced by the current. The next property which a battery displays is its power of igniting and *melting* metallic wires placed between the poles; also in producing *light* by means of charcoal points, equal in brilliancy to that of a little sun, as observed in the electric light. The effect seems to depend upon the combustion, or the decomposition, of particles moving from one pole to the other; the one charcoal point wastes away whilst the other increases by the deposition of the decomposed carbonaceous matter.

We have no *fire*, *heat*, or *light* on earth but what is derived, directly or indirectly, from chemical or electro-magnetic actions. These effects discontinue the moment the conditions and actions are changed, as they solely depend on a constant process of decomposition or oxidation. A body of *water* may with propriety be considered as a *primary liquid*, and may be preserved within a globe without change, and in a quiescent state; but there is no such element in nature as an *incandescent* liquid that can be bottled up like the imaginary igneous nucleus of the earth.

One of the arguments brought forward in support of the *igneous* theory is, that it is found by observations in deep mines that the heat increases at a certain ratio with the depth, and that hot springs and mineral waters are found in all countries. That the warmth produced in the subterranean laboratory should be generally greater in greater depths than near the surface may be reasonably concluded; but we have no proof nor the least indication of there being incandescent matter or *dry heat* within. The fundamental rocks forming the crystalline base are always surrounded by, and saturated with, water. It is *water*, and not heat, that increases with the depth. Indeed, in many places the heat is found greater near the surface than at great depths. The heat in the coal-measures, for instance, is found much greater than in the limestone below. Within the tropics it is *cooler* at moderate depths than near the surface. The temperature of the granites, to the depth of 250 fathoms, has been found on an average less than that of the slates above them. Even granting that the minerals and rocks required their aqueous solutions to be kept nearly at the degree of the boiling-point at the depth of two or three miles, to carry on the subterranean crystalline operations (a depth and degree of temperature we have never reached), it would not follow that it *must* continue to increase until it reached *a dry melting-heat.*

Geologists in general *fancy* that the globe was originally an *incandescent mass,* and that it has been undergoing refrigeration since the creation. How such an absurd and monstrous idea came to be entertained it is difficult to conceive. The globe presents no indications whatever of its ever having been a fiery rocket projected into space to cool. The globe, as a body, is principally composed of *water,* and we find that without water nothing could exist on earth. Indeed, its composition and general aqueous character, irrespective of its atmosphere, render it unfit to receive and sustain the assumed projectile force. Our earth is a beautifully constructed magnetic globe, adapted for the support and preservation of the vegetable and animal kingdoms. Its polar actions, with its rotation and revolution, are more uniform and exact in their movements than the working of the very best chronometer ever made.

According to the *igneous* theory, we live upon a comparatively thin crust (say sixty miles), enclosing intensely incandescent matter!

The arguments adduced in favour of such an extraordinary theory have been the following:—

(1.) That the form of the globe is just that which an *igneous liquid* would assume if thrown into an orbit with a motion similar to that of the earth.

We scarcely need remark that it is *the surface of the ocean* that forms the spherical outline of our globe, and this is clearly shown at every calm following a storm.

(2.) That it is found that heat increases with the depth in mines. It has been shown that the increase of heat is very irregular; and where it is observed somewhat uniform (to about 150° Fahr.), it can be accounted for by chemical action in the *wet* way in the most satisfactory manner.

(3.) That the peculiar appearance of *lavas* all over the world indicates that they proceed from common sources.

These indications simply show that certain rocks have been *altered by a solvent.* That solvent, be it generated by local igneous actions or produced by the ordinary alkaline solutions, must be governed by the laws of chemical changes.

(4.) That on no other hypothesis can we account for the changes of climate indicated by the fossils of tropical character found in the northern hemisphere and the arctic regions. Climates depend on solar radiation, and not on internal heat. The progressive movements of the lands from south to north, zone to zone, from clime to clime, will most fully and most satisfactorily explain all such geological changes.

We have only to admit a well-known fact, viz. the existence of subterranean polar currents, and that these exert a slow decomposing power, like what we see in making experiments with electro-magnetic batteries, and that all substances move from the south pole to the north, to account fully for the terrestrial changes. As all the substances which constitute the crust of the globe are found in *solution* as well as in the solid state, and as all the rocks are more or less saturated, and contain mechanically and chemically 50 per cent. and upwards of water, and in many places such a quantity as to give rise to innumerable mineral springs, the chemical actions must necessarily cause many subterranean disturbances. Judging from the violent effects, on a small scale, which we are able to produce by experiment, a heat may be engendered quite adequate to occasion all that takes place in volcanic eruptions. The predominating volcanoes are *aqueous*, and not *igneous*. The inflammable and incandescent eruptions are very few, and are only occasionally in action, whereas the *watery* eruptions are constant. The sudden fracture of a rock by magnetic tension, and the rapid expansion of the liberated gases, would produce a vibratory jar, and thus give rise to earthquakes and subterranean thunder; and these shocks may be and are propagated hundreds of miles through the medium of the polar grain, or cleavages of the primary rocks from south to north.

The bottom of the ocean (which on an average is considerably deeper than any borings we have made in the rocks of the dry land) is of a lower temperature than the surface. Within the tropics, both in the Atlantic and the Pacific, the surface temperature is about 84° Fahr., but decreases to 40° at about 1000 fathoms deep. Captain Pullen, R.N., of H.M.S. 'Cyclops,' obtained the following results:—In latitude 32° 13′ N., longitude 19° 15′ W., at 400 fathoms the temperature was 50°, the surface being 70°. At 500 it was 50°, but at 800 it was only 44°. In 4° 10′ lat. N., and 28° 42′ long. W., at 1000 fathoms deep the temperature was 42°, and at 1500 fathoms it was reduced to 39°. In lat. 2° 20′ N., long. 28° 44′ W., the temperature was 38°, with a bottom of about 1080 fathoms. In lat. 20° 46′ S., long. 23° 50′ W., the temperature was 35° Fahr. at 2700 fathoms. In lat. 15° S., at the depth of 2254 fathoms the temperature was 35°, and at 2000 fathoms 38°. The minimum temperature at 2700 fathoms deep was 35° in the Atlantic to the south of latitude 20°. Captain Pullen concluded that 35° was the minimum temperature of the great depths of the ocean, and that it commences soon after passing 2000 fathoms. It will therefore be observed that there are no grounds whatever to justify the assumption that the earth contains an *igneous* nucleus; on the contrary, all observations prove that the greatest heat is comparatively near the surface, and that it is produced by the sun's concentrated rays and by electro-chemical action operating in the semi-aqueous crystalline film of the globe from pole to pole.

The variable temperature of the globe, from pole to pole, which gives different degrees of vitality in different zones and heights and depths, depends on *solar radiation* in connexion with the variable degrees of concentration of the sun's rays by the *spherical atmospheric lens* in which we are enveloped.

This concentration of the solar radiant heat towards the terrestrial focus necessarily excites electro-magnetic forces, and thus creates additional and more intense heat in the semi-aqueous shell of the earth, and occasionally gives rise to eruptions or volcanos, analogous to the thunder aud lightning produced in the clouds above.

CHAPTER V.

ON THE EFFECTS OF THE ACTION OF THE SOUTH AND NORTH POLES OF THE GLOBE ON ALL TERRESTRIAL SUBSTANCES.

From a consideration of the general facts that have been stated, it will be sufficiently evident that the surrounding magnetic power acts on the earth in the same way as we observe artificial magnetic batteries acting with solutions between their poles. We have explained that the north pole of the earth is the *absorbing* basin, as the currents move *towards* it, therefore the pole of decomposition; and that the south pole is the *evolving* basin, as the currents move *from* it, and therefore the pole of reproduction. As these polar basins are connected by a conducting fluid, an action must be going on from pole to pole. The ocean and the moist crystalline film of our globe contain in solution acids, alkalies, metals, &c., highly favourable for the circulation of electrochemical action from pole to pole.

The south polar basin may be compared to a perpetual *fountain* to replenish the ocean and the earth; and the north pole, in its mode of action, may be compared to a *whirlpool,* where all terrestrial substances, after fulfilling their destined purposes on earth, submerge and become dissolved again and are finally reduced into their original liquid state.

The Antarctic sea is twice the diameter of the Arctic sea, and more than four times the area. These great basins of electromagnetic activity must necessarily vary in the degrees of their intensity periodically, according to their alternate exposure to the influence of the sun. In December the south polar basin of reproduction is in the greatest activity, and propels large icebergs far towards the tropics; but in the dark region of the north all is comparatively quiescent. In March and September, when the polar basins are equally exposed to the heat of the sun, their activity must be of equal intensity. Hence at these two periods the undulations of the sea and the currents are most turbulent, and then occur what are called in the northern hemisphere "the equinoctial gales." In June the north polar basin is exposed to the sun, and thus the intensity of its decomposing action is increased, while the south polar basin is comparatively dormant during the absence of the sun's rays.

We need not further enlarge on the polarity of the oceanic movements, as it is hoped that the explanations already given will be found sufficient. All the dry lands are more or less pointed or tapering towards the fountain-head of the south, whereas the lands which have been gradually pushed as it were towards the arctic region are old, ragged, crowded, and contorted, having their internal structure more or less disordered. Should any change in the northern hemisphere cause the Gulf-stream to run along the valley of the Mississippi to the arctic basin, the present temperature of Western Europe would be greatly reduced, irrespective of the increased cold which might be expected from a greater proximity to the north pole.

The frigid and temperate zones of the south are very different from the corresponding zones of the north. The temperature, although uniform, is cold and moist. The new lands of the south emerging from the deep are mere sands and gravel, presenting barrenness and scenes of desolation to about 45° lat. S. Icebergs are frequently carried by the antarctic or polar stream to the margin of the tropical zone. Terrestrial operations are in the greatest activity in the southern hemisphere; and much more so than in the northern hemisphere.

Such, then, appears to be the semi-aqueous and the superficial movements observed on the globe. The water and the electro-magnetic actions are found everywhere, penetrating everything, always present, in sight and out of sight, constantly operating in the mineral, the vegetable, and the animal kingdoms, and thus they provide for the wants of generation after generation, to the end of time.

CHAPTER VI.

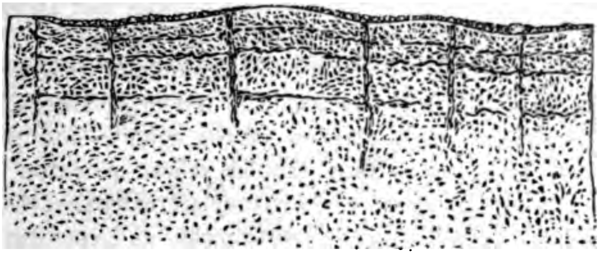
ON THE POLAR, RADIAL, AND FOLIATED STRUCTURE OF THE CRYSTALLINE ROCKS.

The general structure of the globe has been fully explained and illustrated in the Introduction, from page xxii to xxix; but as this highly important subject,—the structure of the primary rocks,—is so little understood even by geologists, we shall furnish further particulars and illustrations, with the hope that they will be the means of removing the erroneous notions now entertained with regard to these crystalline compounds.

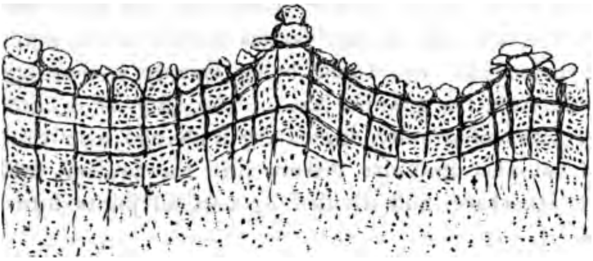
On reference to the common geological ideal section used by lecturers to illustrate the general character of the rocks forming the crust of our globe, it will be observed that the primary crystalline bands, such as the laminated granite, gneiss, mica-slate, &c., are represented as *sedimentary beds*, under the title of the "Cambrian" and "Silurian" stratified rocks. We have shown that the crystalline rocks, although formed and crystallized from water, are not *stratified*, like beds formed from the mechanical deposition of sand and mud; on the contrary, they possess an internal semi-crystalline structure, with vertical lamination or cleavage-planes dividing the masses into vertical bands, as described in the Introduction. In order to make the ideal sections referred to approach the truth, and to represent the primary series as they are seen *in situ*, the bands are curled on the flanks of the granites so as to bring them to the vertical position. Even where the primary rocks are not covered by sedimentary beds, and where their *vertical structure* and their *meridional bearing* are well developed and easily examined (as in Australia and many other places), we have seen most elaborate geological sections made to represent them, not as they are actually seen, but in conformity to *ideal* notions of *sedimentary* beds, contorted into the shape of U's and V's. When professional geologists continue thus to misrepresent the structure of the primary series, we need not be surprised at young students imitating them. Indeed, the general idea appears to be that any given mass of rock with divisional planes *must* be *stratified.*

Mr. Greenough in his "Geological Essays," written about forty-seven years ago, observed that "the word *stratum* is so familiar to our ears that it requires some degree of manliness to acknowledge ourselves ignorant of its meaning; and easy as it may seem to determine whether a given mass of rock be or be not stratified, there is, perhaps, in the whole range of geological investigations no subject more pregnant with controversy." Though so many years have passed away since these observations were made, and though during this period the science has made rapid progress, and though the author, since he has been a member of the Geological Society (now nearly twenty-three years), has taken every opportunity to agitate the question, and to point out the distinction which exists between the laminated bands of the primary series and beds of deposits (illustrating his papers by a section of the Andes, see Plate VII.), yet the word *stratum* is improperly used in connexion with crystalline rocks to this day, to the very great detriment of practical geology as well as to the progress of the science.

In describing the fossiliferous rocks, or real beds of deposits, whether they contain organic remains or not, the term *strata* is correct, however confused the planes of divisions may be. The word stratification implies a cause as well as mode of form or deposition, and that cause is assumed or proved to consist in a *mechanical* deposition, more or less *horizontal*, from water. Crystallization from water will produce *vertical* and *oblique* lamellar structure; and the various aggregations often display foliated, radial, and mammillated structures, as in the formation of an ordinary crystal; therefore these rocks should not be considered as stratified, according to the original definition of that term, *i. e.* beds resulting simply from successive *mechanical deposits.* If geologists continue to use the term *strata* in the same indefinite manner as they have hitherto done in describing the primary as well as the sedimentary rocks, we need not be surprised to find miners and others making use of the word *stratum* in connexion with granite without any definite meaning. We have read reports in which it is stated that "the stratum is granite!" It is necessary to make these observations before proceeding further, inasmuch as it is essential that the reader should correctly comprehend what are the distinctions which are observed between semi-crystalline bands of primary rocks and beds of rocks resulting from mechanical depositions. The normal position of the former is *vertical*, the latter *horizontal*. The granitic and the primary slates belong to the same fundamental formation, the latter being merely a semi-crystalline transition from the granitic base. The annexed section represents a mass of granite, indicating a change near the surface from a compact granular texture into the flat and undulating lamellar structure, and divided by vertical joints into distinct blocks.



This is a very common change in granitic rocks, and may be seen in Devon, Cornwall, Scotland, and Ireland, as well as abroad. Nor is this lamellar structure confined to granitic quarries; porphyritic and greenstone rocks exhibit the same kind of subdivisions, flat or curved, either horizontal or slightly inclined, resembling so much the character of stratification that, had it not been for the vertical planes by which they are intersected, even an experienced eye would at a distance be deceived by them. The subdivisions of the granitic masses by joints and planes of cleavage are seen as perfect as in the real sedimentary beds, but on close examination we find that this structural appearance proceeds from the same cause as that which produces the divisional planes of the crystals of felspar, carbonate of lime, &c. It results from a semi-crystallization, which has a tendency to produce geometrical forms in the aggregated masses as well as in the single crystals. The same power that forms the prism of quartz is also capable of forming a basaltic column. The geometrical forms vary according to the composition of the masses. The following section shows the granitic changes further developed, the entire surface being converted into rhomboidal blocks of granite, many of which become darker and more compact than the parent rock below.

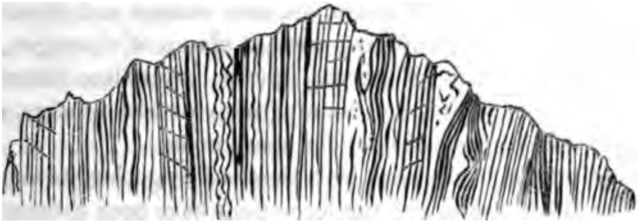


In the 'Report on the Geology of Cornwall and Devon,' by Sir H. T. De la Beche, we find the following remarks:—

"A very general structure prevails throughout these granites, and is more particularly observable in the larger masses. This structure consists in a division of the granite into portions resembling beds, which form tabular sheets of matter in the central parts of the masses; where they are extensive, the edges bend beneath the adjoining schistose rocks, and conform to the surface of the junction between them. The whole, therefore, has the general character of a stratified mass."—"This tendency to be divided or cleave in a stratiform manner is highly deceptive, and has probably given rise to the opinion so frequently expressed at one time, that granite was stratified."—"There are few ravines or coast sections of the granite at its junction with the slate, through which it has been protruded, in which this tendency to divide into stratiform bodies is not observable."—"It is the intersection of the more or less perpendicular joints or divisional planes with this stratiform structure, in the Cornish or Devon granite, which gives it the appearance of being composed of multitudes of rectangular blocks, block being piled upon block, so that in good exposures, as on the sea-coast of the Land's End district, the cliffs seem almost artificial" (p. 163).

It has been already stated that the constituent ingredients of the granitic masses not only arrange themselves to form the granular compounds, but also continue restless whilst they are surrounded with moisture, and remain *in situ*, modifying the structure by divisional joints, slaty cleavages, &c., especially on the outskirts. In rocks, as in crystals, the integral particles are combined and arranged into forms more or less geometrical; if the rocks do not exhibit symmetrical figures like perfect crystals, such as the six-sided prisms of quartz, the oblique rhomboid of carbonate of lime, the cubes of fluor-spar, &c., it may be accounted for by their more complicated composition, their forms not being the simple result of the aggregation of similar particles, but the balance of different forces, each tending to produce a different form.

The micaceous, the talcose, and the chloritic varieties of granite are generally transformed into a slaty structure, and this structure is always found more or less vertical in all parts of the world. This change takes place by the gradual linear arrangements of the flakes of mica and plates of felspar, vertically and longitudinally, and thus finally, after the decomposition of the quartz and felspar, produces the schistose or slaty structure, as shown in the sketch below. (See page 46.)



This section represents the general character of the primary slates, as seen everywhere. At great depths the crystalline base is more or less granitic—that is, it presents the ordinary granular texture, but as we ascend towards the surface the formation becomes laminated, and bands of rock of different characters are thus produced. (See Plate.)

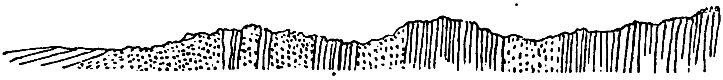
This transition of the crystalline base into the laminated and schistose structure is necessarily insensible; the action being, as it were, a simultaneous growth of the crystals upwards. A micaceous granitic base produces micaceous gneiss (laminated granite), and the latter by degrees becomes changed into micaceous schist. The same with the chloritic and the hornblendic granites. It is simply the laminated structure that distinguishes "gneiss" from "granite," and so the final decomposition of the felspar between the plates of mica and quartz also distinguishes schist or slate from gneiss. It is the same fundamental formation, but changed in structure and in character in the course of time by means of the permanent chemical operations going on below; which actions are as essential to sustain the economy of nature as they are to change the conditions of rocks, and develope and liberate the minerals contained therein. The primary elements which form the base of our habitation have not only to support the lands and seas, but also to decompose, so as to feed vegetable life and nourish the animal kingdom. This could not be effected unless the fundamental base was constantly in a state of activity, working and changing to supply the wants of successive generations. Although the United Kingdom does not present sections so deep as to show the gradual change of the granitic texture into the schistose structure such as we find in the Andes, yet there are sections in Scotland and the North of Ireland sufficiently deep to show these transitions, and also superficially, in the direction of the lamination or the cleavage, for many miles in extent.

On the north-west coast of Ireland and the western coast of Scotland, Norway, and Canada, are seen masses and mountains of crystalline rocks, exhibiting vertical planes of cleavages, and interlaminated bands of granite, gneiss, crystalline limestone, porphyry, slate, quartz, &c., running more or less on edge, without deviation, in parallel lines for many miles.

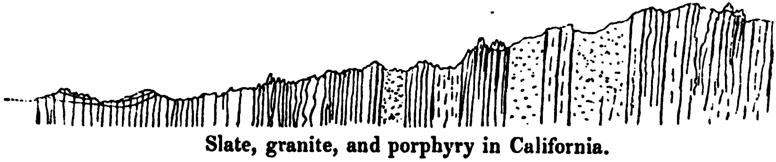
These vertical bands have been *supposed* by geologists in general to be tilted strata, and the formations have been estimated as hundreds of miles in depth! (See the geological description of the "Laurentian" series.)

In Australia these crystalline bands may be traced for hundreds of miles, running north and south on edge, like the rocks in South America and California, thus proving that the order of the crystalline structure must be under the control of polar forces. They are as good as a pocket compass to guide us in travelling in the bush.

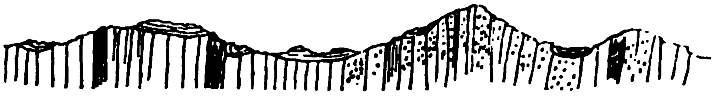
The following sections further illustrate the general character and vertical structure of the primary series, as seen in Europe, America, Africa, and Australia:—



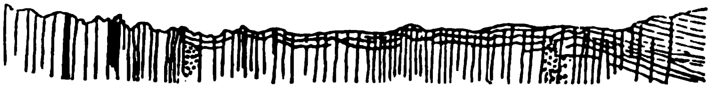
Granite and slate, as seen in Ireland, Scotland, and Norway.



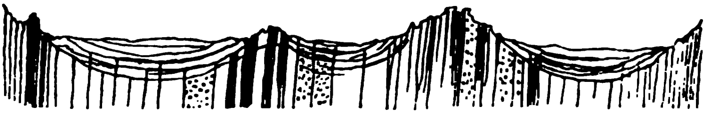
Slate, granite, and porphyry in California.



Granites, porphyrics, slates, &c., in South America.

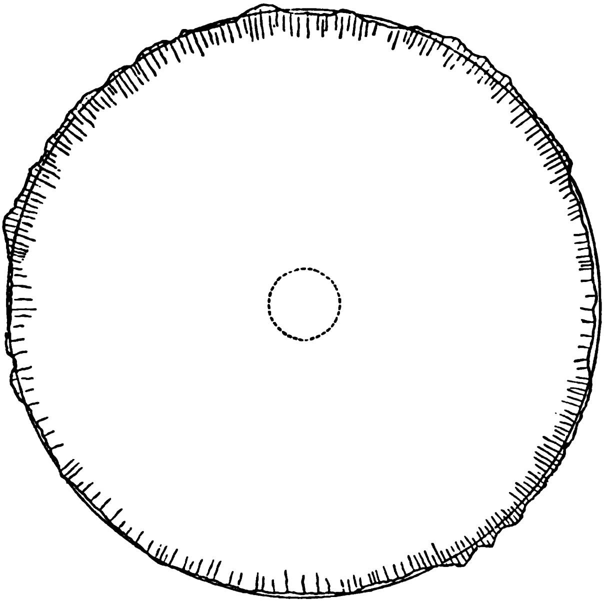


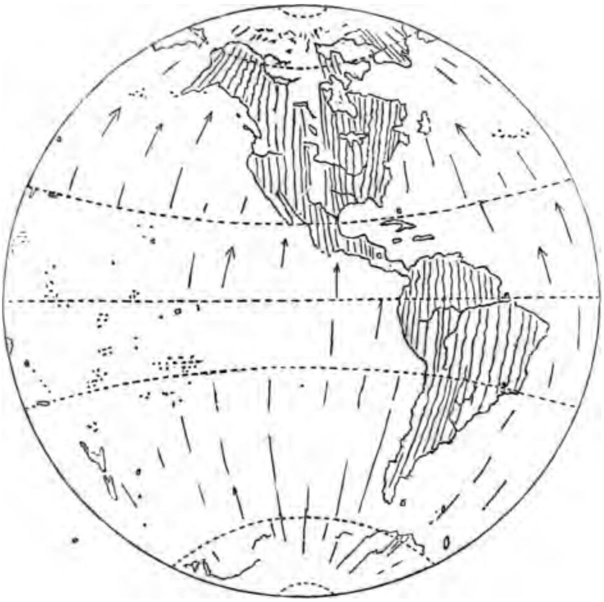
Granites and slates partially covered by sedimentary beds.



Exposed ridges of quartz and slates, with drift and alluvial deposits (in the troughs between) in Australia.

It will therefore be observed that the primary crystalline rocks have a *vertical* and *polar* structure, and are not formed like beds from merely mechanical deposition in water. The following equatorial section of the globe represents the *radial* character of this primary structure. (see Plate VII.)





This radial and polar structure of the primary and crystalline base, affects, in course of time, the consolidated sedimentary beds, and induces and developes therein vertical cleavage-planes, in accordance with the uniformity of the structure below (whatever may be the undulations and contortions of the planes of stratification above), as may be seen in the variety of slate rock which is used for roofing, where the traces of stratification are often obliterated by the reaction of the polar forces.

CHAPTER VII.

ON THE GENERAL CHARACTER OF THE CRYSTALLINE ROCKS, AND THEIR HIGHLY SATURATED AQUEOUS CONDITION *IN SITU*, AND THEIR METALLIFEROUS QUALITIES.

THE first and universal fact that presents itself to our notice, when we examine the internal conditions of these fundamental formations, is, that they contain a very considerable proportion of water.

Water if only slightly acidulated is an universal solvent. The water within the earth's crust contains in solution silica, lime, alumina, in fact all earths and metals; and consequently mineral springs are found everywhere issuing out of the primary series of rocks.

Water is absolutely essential to the formation and growth of the various crystals and minerals of which the fundamental rocks are composed, and is the most powerful agent in wearing away the exposed rocks, and in forming the various sedimentary beds with which the primary rocks are more or less covered.

Penetrate where we will into the crystalline rocks, and as deep as we may, we find water; and we know from experience that without water there would be no activity in the mineral kingdom. Its presence also is as indispensably necessary for the latter as for vegetable and animal life. If we take the limestone rocks, or even the most compact granite, and examine them *in situ*, chemically and mineralogically, we find that, without water, even their solidification would have been impossible, and that each rock contains a very large percentage of water.

In mines we find water containing various metals in solution issuing out of the rocks apart from the masses of minerals. Look at the caverns, not only in limestone formations, but in quartzose slate, and see the beautiful crystals and their gorgeous and variegated colours, forming naturally the richest grottos. All these are produced by the means of water holding the primary elements in solution, from which they crystallize. In a precisely similar way are produced the deposits of flint and chalcedony. Water dissolves at one place and precipitates at another, and conveys matter even mechanically to great distances.

Large trunks of trees have been found silicified *in situ.* There are immense siliceous stumps to be seen in their natural growing position in Chili, Veraguas, Australia, and near Cairo, showing most distinctly that the trees became silicified when in the act of growing by an excess of silica getting into the soil and drawn into the roots. The upper parts becoming decayed, the whole forest appears to have been snapped off by the winds nearly at the same level, as if sawn a few feet above the ground. This silicification, by the process of growth, retains in the most perfect manner the internal structure of the plant. The soluble silica is absorbed into the plant instead of the ordinary sap, and a chemical transposition takes place between the silica and the woody tissues until the stump is fossilized and the tree destroyed.

In mines and all subterranean caverns in the primary rocks, mineral springs and the production of crystals are as constant as the growth of vegetation, and they are formed proportionally to the strength of the solvents, as explained in another chapter.

The same composition always crystallizes in the same form, unless the conditions of the crystallizing body are altered. It has been shown that each particle of a crystalline body has certain points called "poles," which possess definite properties, somewhat analogous to the diverse functions of the roots and leaves of a tree; two distinct points which are diametrically opposed in the greatest activity of converging and diverging actions. This polarity of the particles of matter has been already referred to the influence of terrestrial polarity.

When the animal and vegetable tribes cease to continue the functions of life, a complete disorganization takes place, followed by final decomposition; their respective laws of organization may also be destroyed in their embryo by the crushing of an egg or the bruising of the seed; but this is not the case in the mineral kingdom: the crystal, being the result of a constantly acting force, although bruised, decomposed and dissolved many times over, will again appear in all its perfections. Nothing can destroy the active principle and reproduction of the mineral kingdom.

In the deep recesses of the crystalline film of the earth, the subtile powers of polarity permeate beyond the scene of vegetable and animal life, and a never-ending process is going on, giving form to mineral substances, in all their variety individually and collectively, decomposing and reproducing, and perpetually varying the conditions of the aggregate crystalline compound, which we call the "Primary series," and thus cause the disturbance and the contortions observed therein.

Every elementary body, when placed under circumstances which allow of the free movement of its molecules, has a tendency to crystallize, and the slower the action the more perfect, and the greater the magnitude of, the crystal.

Water holding lime in solution is colourless and perfectly transparent. Let the water slowly evaporate, and the crystals will appear in their usual form and refracting character. These crystals gradually grow until the aggregated calcareous mass forms a symmetric figure, the primary form of each individual crystal being a rhomboid prism.

A crystal thus produced may with propriety be called "Primary," as it is formed from the solution of a primary element, like the crystals of chloride of sodium, sulphate of lime, magnesia, &c. from the sea, into definite forms according to exact laws; and the comminuted and decomposed crystals forming clays, sands, &c., reconsolidated by any cement, may be called a "secondary" or "sedimentary formation." Therefore the terms "primary" and "sedimentary" rocks used here, are to be considered in the same sense, having no reference whatever to the time of their formation.

With regard to the interior of the globe below the crystalline film, nothing can be determined from immediate observation, or by legitimate induction from data founded on experiments, nor is the question essential to our inquiry.

Much importance is placed by some on the degrees of increasing temperature found in our mines to prove igneous fluidity in depth.

The greatest depth towards the centre ascertained by us, is the bottom of the ocean, which (within the tropics) is much colder than the surface, indicating that the heat affecting the surface is solely derived from the sun. The few and comparatively insignificant perforations we have made into the crystalline film are confined to those spots containing minerals in excess, and consequently the seats of chemical activity, and where fresh oxygen is brought in contact with substances to which it has a great affinity, and heat generated during oxidation; therefore, even were there an uniform scale of increasing temperature observed (which is far from being the case), it would not serve as data to found such calculations. The majority of the volcanoes produce hot *water*, alkalies, mud, &c. The few forming slags or lava, show clearly that they are produced by some intense local chemical action, and comparatively very superficial. The fact of their only being in action periodically, shows that they depend on the variable state of the earths or mineral basis, and not on the supposed constant internal incandescent fluidity.

In our investigation of phænomena dependent on natural causes, certain laws of reasoning should inviolably be adhered to. First, no cause should be adduced whose existence is not proved, either by its effects, or by a true process of induction. Secondly, no effect should be attributed to a cause whose known powers are inadequate to its production. Thirdly, no powers should be ascribed to an assumed cause, but those that it is known to possess, according to the laws of terrestrial physics. And finally, no assumed powers should be brought forward to explain effects which are produced by the ordinary powers of nature, which may be, and are daily observed.

If we strictly conform to the above rules, we shall find that the great and various influence of terrestrial polarity enveloping our planet accounts for all geological changes in rocks and on the surface, individually and collectively; whereas we have no positive reason for supposing even the existence of an igneous element in a quiescent state, and much less confined within a hollow and thin semiaqueous sphere. The volcanoes are insignificant pimples when compared to the diameter of the globe. Granting the existence even of an incandescent matter in subterranean caverns, it could not create a solid, but merely the melting of a substance already formed; therefore there is nothing gained by the application of such an hypothesis as the igneous formation of rocks and internal fire.

It is extremely difficult to produce metallic crystals from fusion, and those which are imperfectly formed are produced when in the act of cooling and very slow sublimation; whereas siliceous and calcareous crystals, salts, &c., are not only daily formed in nature from aqueous solutions, but all substances can be crystallized in the moist way, and somewhat rapidly, under the influence of a polar force by artificial means, but not by fusion.

The crystals forming the primary base could never be imitated by fusion, though every other circumstance should occur, and especially those with or without an intermediate prism terminating with pointed pyramids at both ends, which are very common in porphyritic and granitic veins. Those rocks called ancient lava, such as basalt, trap, greenstone, and other variety of the hornblendic series, are of the same aqueous composition as any other rocks; their pores are always more or less filled with water.

All the rocks, the most solid and compact, lose a large portion of their weight when exposed to a strong heat, and many decrepitate; the weight thus lost is mere water. Although heat is employed to expedite the process of crystallization in artificial works, it is not essential for the formation of the crystal. When salts are crystallized, they retain a portion of the liquid not mechanically mixed, but as an essential component, to which their regularity of figure, their colour and transparency are in some instances referrible.

Thus Glauber's salt contains a great quantity of water, and crystallizes in six-sided prisms, transparent and beautiful; expose it to heat, the water of crystallization flies off, the crystal loses its shape and crumbles into white powder. Crystals of gypsum or sulphate of lime are of glossy transparency, and of regular figure; this is due to water: heat them, they crumble into a white powder, well known as plaster of Paris. Such is the aqueous character of the crystals forming the primary base.

Zeolytes lose from 5 to 18 per cent.; compound spar about 45 per cent.; opals from 6 to 18 per cent.; schorl from 7 to 15 per cent.; Brazilian topaz, 20 per cent.; common flint, 5 per cent.; red quartz, 3 per cent.; felspar, from 3 to 10 per cent.; and quartz is often also found hollow and filled with water. In short, water in some proportion seems an essential ingredient in all rocky crystals, and a supersaturation of an alkali will reduce the crystalline into an homogeneous compound, at the ordinary temperature of the internal part of the rocks.

There is scarcely a substance but what is either found in solution, or may be dissolved in an aqueous alkaline menstruum.

The apparent insolubility of quartz gave rise to some of the difficulties which at one time embarrassed geologists; but, as above stated, silica is not only found in solution, but easily dissolved in caustic alkali, and may be obtained like gum-water or glue, perfectly transparent, and of great tenacity, possessing the plastic properties of fine clay. The same plastic character is often found in the felspathic granites in great depths, and especially in the china clay districts.

The ocean may be considered as the primary menstruum or mother-liquid from pole to pole, keeping the mineral crust of the globe in a constant state of saturation and active crystallization, as slightly sketched in another chapter, being a weak compound of all the elements in solution through which the polar force permeates from the diverging to the converging focus of activity. From analogy, and according to many experiments made with a battery in connexion with a globe of ten inches diameter, crystallization commences at the diverging or hydrogen pole, and these crystals form lines until they extend to the converging or oxygen pole in symmetrical meridian lines, and thus producing a polar grain from pole to pole. The extreme ends of these linear crystalline growths oxidate as they approach the north or pole of convergence; and as fast as this end is oxidated and dissolved, the same amount of new crystals is formed at the diverging poles, and both crystals and water are propelled from the hydrogen to the oxygen poles, or, in other words, from south to north; and thus producing the northward movement which we observe in nature, that is, the constant northerly currents of the Pacific and Atlantic oceans, and the northward action of the polar cleavage of the primary rocks, together with those polar effects we observe in mineral veins.

In all the primary rocks in every part of the world, where they have been carefully examined, we recognise in every crystal, and the compound crystalline masses, the action of these constant forces of polarity and chemical affinity, giving to each mass a polar grain, and to every crystal a definite form and composition in accordance to the general law of action already explained; hence the above may be considered an experimental demonstration of the observed natural truths and totally free from all assumptions, and has been for years as useful in practice as correct in principle, which is the true and proper test of a correct theory.

The principal elementary substances entering into the composition of the crystalline rocks may be considered the following:—

Silica,
Alumina,
Magnesia,
Potash,
Soda,
Lime,
Iron,
Manganese,
Fluoric acid,
Boracic acid,
Carbonic acid,
Sulphuric acid,
Muriatic acid,
Nitric acid,
Water,
Oxygen and Hydrogen.

The aggregated crystalline compound consists of the above in a state of gaseous fluids, semi-fluids, and solids; the solid elements being in different stages and degrees of crystallization.

Silica forms	Quartz.
Silica, alumina, lime, potash and soda	Felspar.
Silica, alumina, potash and iron	Mica.
Silica, alumina, magnesia and iron	Chlorite.
Silica, magnesia and potash	Talc.
Silica, alumina, magnesia, lime and iron	Hornblende.
Silica, alumina, magnesia, potash and iron	Schorl.
Lime and carbonic acid	Carbonate of lime.
Lime and fluoric acid	Fluor spar.
Lime and sulphuric acid	Sulphate of lime.

&c. &c. &c.

Besides the above ingredients, there are also disseminated in the crystalline rocks, or in a state of saturation, all the known minerals, and these even may likewise be compounds of which hydrogen forms a part.

Hydrogen gas dissolves iron, zinc, arsenic, sulphur, carbon, &c., and from combinations thus formed, we can with facility separate these elements. Such substances may exist in rocks, and in our atmosphere, without our being cognizant of them, and thus supply the required substances for the formation of the aërolites of iron and nickel.

The aggregation of the above crystalline substances constitutes what we call *granite*, and which we necessarily consider as the primary crystalline base of all our known rocks.

Numerous names have been given from time to time to the different kind of granites, but it is very evident that such distinctions can only be governed by the predominance of some, and the deficiency of other, ingredients in the compound.

In order to have some idea of the mineral character of the granitic base, as observed in both hemispheres, we shall enumerate the following:—

Quartz, felspar and mica	Common micaceous granite.	
Quartz, felspar and talc	Talcose	ditto.
Quartz, felspar and chlorite	Chloritic	ditto.
Quartz, felspar and hornblende	Hornblendic	ditto.
Quartz as homogeneous compound	Basalt, trap, &c.	ditto.
Quartz with crystals of felspar	Porphyritic	ditto.
Quartz and talc	Quartzose	ditto.

&c. &c. &c.

Felspar in general constitutes by far the largest part of the granite, and is the active agent of decomposition, owing to its alkaline character, and is the principal agent by which the silicates or compounds of quartz and metals are separated in the laboratory of nature.

When silicates, mica, talc, &c. predominate, these crystalline flakes are gradually drawn or grow out as it were from the granitic base into a fibrous or laminated structure, the respective ingredients (as explained in another place) become formed into thin, vertical, parallel plates, known as cleavage or polar structure; and sometimes into elongated fibrous bars, well known to quarrymen who are accustomed to split granite and slate rocks according to the grain. This change is always found in meridional bands, as already explained, proving distinctly the influence of polarity in the molecular arrangement throughout the compound.

This elongated structure or laminated granite is called gneiss, being identically the same chemical compound as the granitic base. The transition of the crystalline aggregation to the laminated structure is necessarily insensible, the action being like a simultaneous polar growth of the respective varieties of granites northward; hence a micaceous granite produces micaceous gneiss, chloritic granite, chloritic gneiss, &c., as seen in the section of the Andes.

Schist and clay-slate form the external termination of the great granite masses, being their respective oxidated crusts; branches and leaves as it were of the great granitic trunks. The mica granite passes first into gneiss, then into mica schist, by an almost imperceptible gradation, as illustrated in Plate VIII.

This slaty portion of the primary is often confounded with sedimentary rocks, and from its constant state of activity, it frequently obliterates sedimentary seams, and cleaves the superficial beds at right angles to the horizon, giving the superincumbent strata a polar structure, as commonly observed in roof-slate quarries and described in Chap. IV. It is the final decomposition of the felspar between the plates of mica and quartz that distinguishes slate or schist from gneiss.

The felspathic granite, especially when supersaturated with lime or potash, never produces the above schistose variety, but exfoliates along the undulating surface, and changes into brown compact clay-stone, called killas, a compound of silicate of alumina, variously coloured according to the quantity of the peroxide of iron present. This is the general character of the killas of Cornwall, lapping on the granites and porphyries. These clay-slates are seldom schistose.

It is within the limits of this transition of the crystalline base into the oxidated compound that the minerals become principally developed in veins, &c., neither very deep into the perfect crystalline, nor yet far off from its termination into clay-slate. This variety of clay-slate is generally productive in copper and tin, and also in gold and platina, in the auriferous granite districts.

Each series of granite and schist, or granite and its clay-slate, belongs to one formation, and each variety along the line of cleavage is essentially composed of the same minerals variously modified, decomposed, &c. by polar influence, and their individual and chemical affinity; passing by insensible gradation from the base to the slaty structure, in vertical plates, in meridional direction, and finally into massive clay, and subject to constant changes and disturbing local causes.

When the cleavage planes are not developed in the exfoliated and massive variety, there is nevertheless an action passing through their *pores* in the same polar direction as the cleavage planes; and this constant force gives rise to the great meridional splits called cross-courses.

Besides the regular transition of the crystalline base into slate, &c., there are also veins formed interlaminated in the series. Should the base contain a large proportion of silica, quartz veins will be formed within the planes of cleavage, or in the transverse fractures filled by the pores of the rock; if calcareous solutions prevail, carbonate of lime will be formed; and if magnesia and potash, talcose, schist and serpentine veins; these again, united with hornblende and lime, with iron and carbonic acid, will form veins of basalt, trap, &c.: the last varieties are the most active compounds in all rocks; hence the cause of their being called volcanic rocks. The felspathic varieties are found the richest for minerals in every part of the world. The quartzose granite and the homogeneous dark hornblendic rocks are the most unproductive.

When a primary crystalline rock has a moist massive and grey base, and somewhat porphyritic, it is seldom deficient in mineral; but when comparatively dry, with a distinct crystalline grain without a base, it is generally poor in minerals. The metalliferous parts of Cornwall have a porphyritic granite, predominating in characteristic quartz and felspar, which on the surface is partially decomposed or changed into compact brown rock (killas); and the intermediate part is called elvan, being a fine-grained porphyry. The presence of talc and white mica indicates scarcity of minerals, if the proportion be great; however, we must remember that small masses of poor rocks may be found inclosed in the richest series; it is therefore necessary to be guarded before drawing conclusions from isolated cases.

The first fractures produced in any series of rocks are filled with the predominating elements—silica, alumina, lime, &c.; hence we find first veins of granite, elvan, quartz, &c., and mineral veins only become formed after the siliceous and other earthy matter are nearly exhausted in the respective metalliferous bands; we therefore find that the mineral intersects these quartz and porphyritic veins.

As the process in the primary rocks is constant, and the pores and cleavage being always more or less charged with mineral solutions and subject to variable tensions, fractures, &c., the structure of the compound becomes occasionally very complicated, by which cause the phænomena of heaves, splits, veins, &c. are produced, which will be explained in the following chapters.

In Chili, Peru, New Granada, Canada and Norway, grey ore, native copper, and flakes of native silver are frequently found diffused or interlaminated in micaceous schist and gneiss. Gold is also found in flakes in the lamina of the micaceous and argillaceous schist of the Brazils, New Granada, Central America, and California; and the oxide of tin is also found disseminated in schorl granite.

The formation of sulphuretted ores which are sometimes found impregnating porphyritic rocks, as well as in lodes, was formerly considered as scarcely explicable in the moist way, sulphur being supposed insoluble in water; but we find numerous springs issuing out of the crystalline series holding sulphur in solution, sulphuretted hydrogen, &c.

A cubic foot of water may contain about 400 grains of sulphur. Carbonate of lead is soluble in alkali and lime, and may be precipitated therefrom by sulphuretted hydrogen. Lead is more attracted by lime than by other earths, and limestone formations contain lead in preference to other metals.

Pieces of timber have been found in the mines of South America covered with siliceous and calcareous spar, and in Peru and Chili, grey and red silver ore, copper and iron pyrites, are frequently found formed in old workings. What is called by miners "young mundic," is of common occurrence, and is a new crop of sulphuretted ore found forming in old mines in South America and other places: a fresh crop of fine crystals has been found in gold mines like an efflorescence on the walls, and on the rubbish in the lodes, and in some instances sufficiently rich to pay for the labour of clearing the walls and refuse. It will therefore be evident that the mineral kingdom is like the vegetable, moist, and in a constant state of activity; and although this action is invisible to those who are confined to the surface, and so slow as not to be perceptible to the multitude, allowing them to build and live undisturbed; it is, nevertheless, sufficiently active to provide for the wants of all generations, and constantly forming mineral veins from a mere line, or joint, into thick crystalline masses; and these within the reach of our subterranean industry.

CHAPTER VIII.

ON THE PRODUCTION OF GOLD, THE OXIDE OF TIN, AND OTHER METALS, IN THE STREAMS RUNNING FROM THE PRIMARY SERIES OF ROCKS.

There are many strange ideas regarding the origin of metals found in streams, such as the gold in the sands of California, Veraguas, Choco, Brazils, Africa, and Siberia, and also the tin in the streams of Cornwall, Devon, and in the Indian Archipelago. Some imagine that they are the produce of large lodes or veins, whilst others fancy that they are the production of metallic showers thrown up by some extraordinary volcanoes at some particular epoch in the history of our globe. Such loose conceptions proceed from persons who have had no opportunity of studying the real character of these deposits *in situ*, and more especially in those countries where such deposits are daily forming from the gradual disintegration of metalliferous granites and other primary rocks.

Gold, platina, and other metals not subject to oxidation, are frequently found in the debris of a certain variety of granites, porphyries, and their respective clay-slates. These productions depend on the *composition* and *structure* of the primary crystalline rocks and the degree of richness in which the metals are disseminated therein, and the internal chemical action by which joints and crevices are becoming gradually filled with metals, or are crystallized in the oxidating superficial exfoliations of the rocks. These superficial productions, of gold and platina especially, far exceed the quantities obtained from veins, and the metals thus extracted are much purer than that produced by the latter. We likewise find that auriferous rocks are much subject to decomposition, and thus producing and liberating their metallic contents in the divisions of the exfoliated surface, and only rarely in great fissures or lodes, like the sulphurets of the baser metals; and even in these rare cases the precious metal is found mechanically mixed in lodes of iron pyrites. This superficial process of metallic aggregation and decomposition in the auriferous rocks is *constant*, more or less, in every region on the face of our globe, depending entirely *on mineral and physical conditions*, confined to no age, nor to any particular zone.

Many have imagined that the Ural gold-works in Russia were lodes, or veins worked underground in the hard rock, like copper and lead lodes, instead of which, they are principally on deposits, *i. e.* on the detritus or shingle accumulated on the slopes of the ridges and adjacent ravines and plains. The only subterranean works carried on there in the compact rock are those confined to small auriferous quartz veins, yielding, if any, but a slight profit. The gold quartz veins are very deceptive, generally speaking, sometimes glittering with gold on the surface, and with large masses in fractures, yet at a few fathoms in depth scarcely affording sufficient gold to pay the cost of extraction. Yet these very rocks, when left to the natural processes of decomposition and internal metallic aggregation, produce rich debris at their base. Hence no native washer will work in the compact quartz rock for gold whilst he is able to obtain *unwashed* deposits. The most productive gold veins to a moderate depth are the auriferous pyrites, such as the St. Juan del Rey in the Brazils, and Marmato in New Grenada. The former is in clay-slate, and the latter in porphyry: the gold thus obtained is of a low standard as compared to the superficial production from quartz. The banks and slopes of the tributaries of the Sacramento in California are strewed over with the debris of the auriferous rocks forming the Sierra de Nevada; the deposits being enriched by concentration in pools and other mechanical obstacles to the streams of water; and these deposits diminish in quantity, and are coarser in quality, as the acclivity of the mountains increases. This chain of mountains is similar to the Choco in New Grenada, viz. great ridges running more or less in the meridian, composed of immense parallel bands of auriferous granites, gneiss, porphyries, chloritic slates, hornblende, and quartz rocks, intersected transversely by the deep ravines above alluded to, as illustrated in Plate VII. (Section of the Andes).

The gold washings of El Mineral de Veraguas were once very productive, and are still the most important in the Isthmus of Panama. However, like other old gold washings, the accumulated auriferous debris of the hills and valleys have been all washed over; no important gold lodes have been discovered, and the gold quartz veins not being found sufficiently productive to pay cost beyond the surface, the natives relinquished the task, and are now rewashing the old sands together with what is brought down by floods from the flanks of the granitic chain. The gold obtained from these washings is of a large grain in the higher parts of the ravines, and diminishes to a very fine grain down in the plains, and is of a high specific gravity. The natives of the gold districts are generally expert washers, and know the localities where the gold mostly accumulates, and the kind of rocks which produce it. To an European these gold-washing scenes are pictures of misery; the diggers and washers toil and live like the beasts of the forest, feed on the coarsest food, and sleep often without shelter. The great inconveniences attending the washing for gold, are the necessity of being almost constantly in the water, and the laborious work of removing the large stones to get at the inferior deposit, which is the richest for the precious metal. This kind of work is precisely similar to that carried on in the tin stream districts on Dartmoor, Bodmin Moor, St. Austell, &c., all of which must be done by manual labour. The extraction of the gold from the sand after the auriferous bed has been taken up from under the stones, is easily effected by means of screens, and perforated plates fixed on hollow inclined trunks, with a small stream of water running over. The washing process is easily done by various simple methods, and the light sand is carried away by the stream of water, leaving a black ferruginous substance behind, in which the gold is usually enveloped.

By bruising and washing the most compact quartz in the auriferous granites and porphyries, we detect gold in an impalpable state of dissemination, forming, in fact, a portion of the compound, like the salt in the sea; but it is in the small fissures only, or in the vacuities of the oxidating crusts, that we find the granular or massive gold formed, by the process of crystallization which is constantly going on in all moist rocks.

In the *hard compact* crystalline rocks in depth the gold is never found in grains; it is only detected in a very minute or aqueous state of saturation by analysis, or by very fine grinding and most careful washing; but after the change of the quartzose crystalline into the clay-slate or silicate of alumina, the gold becomes granular, and is deposited in flakes, crystals, &c., in the cleavage and fractures of the rocks. In Gongo Soco the gold is found in the jacotinga formation (ferruginous clay-slate), in some parts sufficiently rich to quarry the rock to obtain the gold disseminated therein. The same has been observed at Morro Velho. The clay-slate in which the lode is formed is often found to contain from 1 to 1½ oits of gold per ton, and where this rock is fractured, rich veins of gold are necessarily formed. When these rocks decompose they supply the valleys with gold sands. The stanniferous granites of Cornwall present similar instances; the oxide of tin forms frequently a component part of the granitic masses, and when such rocks decompose, they necessarily cause rich deposits of tin in the bordering ravines.

The largest proportion of gold is obtained from rivers and superficial deposits in granitic districts; the quantity extracted from veins is comparatively small, less pure, and depreciating in quality and amount at moderate depths. Gold is always found in its metallic state, almost pure in alluvial deposits, but more or less alloyed, when found in veins with minerals. There are no *ores* of gold, as often very improperly stated. This metal is never found mineralized in nature, but enclosed commonly in iron pyrites, and frequently alloyed with other *metals.* The gold-producing rocks are not confined to particular geographical zones, as formerly supposed, but are found protruding more or less in meridional bands in all countries where the primary series is visible.

All the ferruginous and friable granites, containing yellow mica and pale yellow quartz, which are subject to disintegrate into spherical masses, produce gold in grains during the change. The auriferous granites bordering the Pacific Ocean, as well as those situate in the interior of the Americas, which I have minutely examined, show this effect in a very striking manner. The internal crystalline character of the auriferous granites changes as it approaches the surface by an almost imperceptible gradation into a kind of globular structure, like a coarse conglomerate, as represented in Plate VIII. This section was taken on the banks of the Rio Negro in New Grenada, and is, indeed, characteristic of the generality of the changes taking place during the process of decomposition and production of gold on the flanks of auriferous granites.

In depth we find the usual crystalline aggregation of quartz, felspar, mica, and sometimes hornblende, confusedly mixed; a specimen broken from which, ground to fine powder, will show a trace of gold in an impalpable state, but so light as to render it impossible to detect any appreciable quantity by the mechanical operation of washing. But, as we ascend, we find the crystalline aggregation passing, by an insensible gradation, into a spherical structure (as illustrated in Plate VIII., to which I beg reference); the respective nucleus of each centre of attraction becomes denser and harder than the parent rock by the concentration of the surrounding silica, like the formation of flints in chalk. Each nucleus becomes enveloped by a series of concentric envelopes, which enclose (as this structural change approaches towards the surface of the rock) an efflorescence of ferruginous mineral, containing gold in grains. These grey compact siliceous centres are called by the native gold-washers in South America the "madres," or mother of the gold, as without these rounded nodules they seldom find sufficient gold in the debris to make it worthy of the labour of washing. The gold, as already noted, is in such a minute state of dissemination in the uniform crystalline base, as to make it almost difficult to detect the mere trace of it; but in the oxidated and decomposed crust the metals become aggregated to different centres, and form into grains, easily caught by the ordinary washing process.

The stony nuclei, as well as the concentric rings, are completely deprived of their original auriferous contents by this process of internal aggregation. After these oxidated crusts are brought down by the torrents, and washed away from the foot, or from the ravines of such mountains, the gold-washers must remove to other localities, or wait a few years until this slow process of nature supplies them with a fresh crop, as they know to their cost that it would be useless to penetrate very deep into the hard rock in search of the metal, as it must have a vacuity or a fissure for its formation.

Friable granites are exceedingly productive of alluvial deposits. The gold deposits of California, as already noted, are precisely of the same character, the quantity of the available gold being limited to the amount of the decomposed debris accumulated in the ravines, with the exception of that formed in the upper portion of the quartz rock. I know of no primary rocks of the above composition of quartz and felspar, and the friable ferruginous granites, with bright yellow mica, but what contain gold.

Gold and tin, if not embodied or overpowered by strong polar substances, such as sulphurets of iron, copper, or other compounds of similar polar tendency, remain in the crystalline base in the disseminated state, and only become developed by crystallizing or efflorescing towards the surface. If mica, talc, or chloritic flakes, happen to be in excess, they will produce a fissile structure, the longitudinal action generated by which causes tension, and consequently a series of transverse fractures in the more friable parallel and enclosing bands. The surfaces of these internal planes or fissures become gradually coated by the metals the rock may contain, and thus form longitudinal and transverse veins. But if felspar happen to be the predominating ingredient, and this strongly saturated with iron, or any other substance susceptible of rapid oxidation, or if the compound be very friable, the exfoliated decomposition will ensue; the free silica aggregates into centres, the felspar is reduced into clay, the metal collects into grains, disintegration takes place, and the thin, loose, friable surface is gradually washed into ravines; the heavier substances fall to the bottom, and accumulate in pools and other parts of the stream presenting the greatest resistance, whilst the lighter particles are washed away by the torrent. Such is the general character of the deposits of the gold and tin stream washings. These deposits are therefore the product of friable metalliferous rocks, and not derived from lodes. The metallic contents of such rocks can only become available by this process of slow decomposition. The value of these deposits depends on the superficial extent of the metalliferous rocks falling to the ravines and the plains, to receive the accumulation of centuries. It will be easily conceived, that works of discovery, carried into the hard crystalline base to a great extent *beyond the deposits* in such rocks, must prove fruitless; and if such explorations be carried on by men who have no other knowledge to guide them underground than the occasional specks of mineral in the rocks, priany, quartz, &c., their reports would be "kindly and promising" until doomsday, and consequently an immense capital would be wasted away in unprofitable works, and which has been the case in almost every gold mine carried on by Europeans.

Gold has been often found in the tin streams of Cornwall, and is frequently associated with the oxides of this metal in the schorlaceous granites, and in the gossans (the oxidated portion of the lodes), and also in the ravines intersecting the ferro-felspathic rocks of Scotland. When the gold was discovered in the streams of the Ballin valley in the county of Wicklow in Ireland, almost the whole population of the neighbourhood flocked like the Californians, to gather so rich a harvest, and actually neglected at the time the produce of their fields. Stream-works were established and continued for a few years, and the products left a surplus over expenditure, and some large lumps were found. This, however, was soon lost, as well as another capital added to it, owing to the mistaken notion of the existence of a *mother lode,* whence it was supposed the fine deposit of gold came.

The best miners of the old school were consulted and encouraged this idea; the solid mass was soon intersected by numerous trenches, levels, shafts, &c.; every quartz string was driven through, under the impression of finding the grand source of this wealth, but of no avail; with the exception of occasional grains in vacuities or joints, nothing was found worthy of notice, and the undertaking was abandoned. Yet these same valleys still furnish a small amount of gold annually, and will continue so to do whilst the granitic domes remain subject to decomposition.

The intelligent and real practical Cornish miner, more especially in the stanniferous districts, is getting now so well acquainted with the character of the crystalline rocks, that he knows from mere appearance of a specimen what kind of granite will produce tin. Schorl appears to be an essential ingredient, or at all events, a constant associate of the oxide of tin.

In Dartmoor, St. Austell, and the Land's End, the oxide of tin is in some places so much disseminated through the schorlaceous granite as to render it worth quarrying for the extraction of the tin. All the metals that are found in this disseminated state are always more pure than when in veins. Those elements which produce joints and fractures, and veins in the crystalline base, form the accumulation of the metals in the recesses at the expense of a considerable amount of alloy of mineralizing substances, such as iron pyrites, the arsenical pyrites, &c., consequently metals obtained from veins are never so pure as those procured from the decomposition of metalliferous rocks; when dispersed in the latter they are comparatively unalloyed. It is important to bear this constantly in mind, when we have to consider the merits of such productions in an economical point of view.

The stanniferous, like the auriferous rocks, are often very friable, and subject to disintegration; the felspar decomposes into clay, according to the character of its component parts; an exfoliated oxidated crust is formed, which is gradually washed down to the ravines, where the several substances are deposited, according to their respective gravities; the oxide of tin, being the heaviest, will occupy the lowest beds in each accumulation. There was a time when the most intelligent old tinners did fancy that these alluvial deposits of tin came from lodes, but, fortunately for our industrial science, such erroneous notions are now almost matters of history with practical men. Some vain attempts have been made to determine the age of this superficial detritus of stream tin, and its associated gravels, but to no purpose; it is like that vague term, diluvium, it belongs to all ages, only more active perhaps at some periods than at others from local and physical conditions. Sometimes we find the tin-stone pebbles, the comminuted quartz grains, and the oxide of tin, left behind on the parent rock, and the decomposed felspar washed away; and this covering becomes so thick, as to prevent further decomposition.

In the Indian Archipelago the same phænomena occur, especially on the island of Banca. This island, with its ridges, conforms in its direction to the Asiatic ranges of mountains, *i. e.* running north-east, and is composed principally of granite, both ferruginous and schorlaceous, the predominance of the former giving it a general red colour. The oxide of tin is disseminated more or less throughout the schorlaceous granite, and is found in beds at the foot of the granitic range, either immediately under the surface or at no great distance below it—the greatest accumulations are mostly found in low situations near the schorlaceous ridges. These deposits are composed of clay of various colours, from pure white to yellow and red. The most productive beds of tin ore have been found near the central parts of the peninsula, at the junction of the districts of Sungiebulu, Klábbet, and Tengá.

The lowest bed is generally of the purest white colour, very light, and adheres strongly to the tongue, like pure clay, on which the ores of tin are deposited in layers, differing in richness and extent according to the locality and quality of the parent rock. Sometimes the tin is found dispersed through the whole of the bed, commencing immediately under the soil, and increasing in quantity towards the bottom. The schorl in the granite is often seen in black strings, intersecting each other at different angles, and also in elegant needle-form crystals, which renders the granitic mass loose and friable. In some parts the minute particles of schorl are barely perceptible; in other portions this substance is uniformly mixed through the stone, and again the granite changes into a different compound, in which schorl cannot be detected. In all the stanniferous granite rocks the mica is but sparingly distributed, the admixture being quartz, felspar, and schorl in variable proportions. The exfoliated beds formed by decomposition *in situ* on the surface of the granite, consist of fragments of quartz and felspar, with small particles of schorl and the oxide of tin. Sometimes coarse fragments of decomposed granite are seen with breccia, through which the oxide of tin is disseminated. The productiveness of the deposits of the valleys gradually diminishes as the acclivity of the hill increases, similar to gold washings, and thus plainly showing the origin of these alluvial deposits. All persons engaged in such works should never forget this most important fact. These superficial processes of decomposition and deposits are constantly going on in every region of the earth where the primary rocks are exposed to the atmosphere.

CHAPTER IX.

THE DIFFUSION OF MINERALS THROUGH ROCKS.

Rocks impregnated with minerals, as well as the precious metals, are not only of common occurrence in foreign countries, but also well known in England, and have been most fully described by Mr. Henwood in the Transactions of the Royal Geological Society of Cornwall, vol. v. Granules of tin ore are found dispersed through, and form an integral part of the granites of Dartmoor, Kit-Hill, Bodmin Moor, St. Austell in Carclaze, Crowan, Godolphin, and the St. Just districts, and more especially in the pot granite. We find the tin also disseminated through the elvans of the granites and clay-slate flanks in all the stanniferous formations of Cornwall and Devon, being in fact a component part of the rock, and not brought in by means of any fissures. Copper pyrites also forms an ingredient in the slate of North Wales, some of the slates of Cornwall (Wheal Music), and in the granite at Wheal Vyvyan, and is indeed very common in the large masses of quartz rock. We find the ore disseminated through these rocks just in the same manner as in the "caple" lodes, excepting that it is more thinly sprinkled. The segregation of these specks of ore, when they are not formed in lines of regular bearing, forms the nodules and other irregular and unconnected masses dispersed through the rocks, as seen in many parts of North Wales, Virtuous Lady Mine near Tavistock, and Ireland. When these rocks happen to be fractured, they favour the linear segregation of the ore within, and thus form veins of clean mineral. This effect can be well observed in the stanniferous granite; where the surface is broken into fissures, the tin ore becomes aggregated in the joints, and in the course of time renders such joints or fractures very productive. These kind of veins containing tin in granite, seldom continue very deep; they are principally limited to the upper exfoliated separation of the friable part from the harder nucleus below. It is only near the flanks that they continue even to a moderate depth in the granite. We find also that the most productive portions of such fissures or lodes are in the valleys and flanks of the granitic ridges. The tender parts, which form valleys by disintegration, indicate the richest portion of the intersecting lodes, *i. e.* the most favourable for the aggregation of mineral substance, and the hard, compact, and high ridges the unproductive. It is the gradually wearing down of these soft and productive bands of granite, that forms the tin-stream deposits noticed in the previous chapter. Many persons, and indeed many of those called practical miners, have an idea that it is the lode that brings in the ore, and consequently they think that they ought to be as rich in the ridges of the granite as in the valleys, or in one part of the lode as well as another, even miles long through various qualities of rocks; and thus lead capitalists into many unprofitable speculations. As, therefore, the productiveness of lodes depends on so many internal conditions, both in the mechanical structure and mineral composition of the rocks, and chemical activity from aqueous saturation, as well as on the angular position of the lodes themselves; and as daily experience shows that the same character of rocks assumes very different values in their metallic contents in different districts, from the want of the combined favourable conditions, *i.e.* granites, clay-slates, and their junctions, it becomes necessary to be extremely guarded in drawing conclusions, and nothing short of very long and extensive experience in every description of mineral districts can qualify a person to give a correct report on an unexplored ground.

It is lamentable to see the loose and extremely incorrect reports commonly made by incompetent persons, which lead to so much waste of capital. We frequently observe the term *strata* employed in describing the formation of *granite* in some of our mine-agents' reports, showing clearly that they do not understand the definition of strata or stratified rock, and much less correct reasoning from analogy.

There are also masses of mineral in granite and slate called pipes, carbonas, &c. These are large and long masses of ore, generally in a slanting direction, but sometimes perpendicular like the trunk of a tree, with roots, enclosed in or surrounded by the rock. They are found very oblique in the granite of St. Ives, neither appearing at the surface nor extending far downwards, having both roots and branches, the main mineral trunk being about ten feet diameter in the middle. It often happens also that minerals accumulate in "floors," *i. e.* in the horizontal or oblique joints. To conclude, we may briefly state that minerals grow out of rocks into all kinds of fractures, joints, cavities, &c., and the smaller masses broken from the small veins of the parent rock represent exactly the phænomena of mineral veins on a small scale, in character, contents, and dislocations. We shall enter more in detail on this interesting question in another chapter, and then show that a very slight variation in the appearance and position of rocks indicates different productions of metals, and respective quantities, such as gold, tin, copper, silver, lead, &c., with their compounds.

CHAPTER X.

ON THE UNIFORMITY IN THE ORDER OF THE STRUCTURE AND JOINTS OF THE GRANITE AND OTHER PRIMARY CRYSTALLINE ROCKS.

The development of the structure of crystalline rocks, by a partial and incipient decomposition, is dependent on the same principle as that by which the crystalline texture of mineral and saline masses is disclosed by the action of a weak solvent. Wherever a large section of granite is exposed to the atmosphere, its surface becomes divided into joints and fissures, preserving almost exact parallelism amongst themselves, thus producing internal forms of cubes, rhombs, and spheroids. When these blocks become much exposed to the action of the elements, they are gradually converted into quadrangular piles, as if built into isolated towers or pillars, or spheroidal masses. These structures and subsequent changes depend more or less on the composition of the granitic rocks. The ferruginous granite exhibits the most perfect spherical concretions; the common granite, especially the felspathic, the cuboidal; the fine-grained granite disintegrates into tabular masses; the schorlaceous granite and shorl-rock often assume the prismatic form, and this is also observed in the hornblendic variety.

The common reduction of the granitic concretions to the spheroidal form, by the action of the elements, is also a property belonging to greenstone, basalt, and other hornblendic and trap-rocks, as observed at Panama, Cauca, Choco, &c.

We find not only globular aggregation of very fine and hard granite, but also the constituent parts of the mass so disposed around common centres, as to form concentric layers, as already explained in the chapter on Gold. These changes may be observed in Corsica, Norway, the Western Isles of Scotland, Brazils, Choco, Panama, California, &c. These nuclei are often found as perfectly spherical as cannon-balls in the gold-washing districts, and have been used by the Turks for that purpose in their batteries.

The spheroidal structure is not confined to the component concretions of the granitic rocks, but is likewise characteristic of the entire masses, the surface of these crystalline masses being generally of a rounded form or dome-shape, and traversed also by exfoliating subdivisions conformable to the curves and undulations of the surface. We may, from the appearance of the configuration, determine approximately the composition of the crystalline base. The granite is not only traversed by systems of parallel joints, as already stated, but is also capable of being cleft in directions corresponding therewith, so that the masses can be subdivided from the large to the smallest scale, according to the character of the fundamental structure, as described in the chapter on the polarity of cleavage. Large masses of granite may be cloven into cuboids, where the joints are not visible, and thus form blocks corresponding in form to those developed during the action of decomposition. The quarryman from experience can detect the grain in granite, and by boring several holes in the direction of the grain, cleave the granite into regular quadrangular masses. Such is also the case with gneiss and primary slate.

Quarrymen are well acquainted with this fact, and therefore never attempt to split the rock in a line diagonal thereto. The main split lines of the Cornish and Devon granites, like those of other countries, run more or less parallel from south-west to north-east, being in the same bearing as the cleavage planes already described, which, in fact, are the continuation of the same planes. See Plate VIII. This may be considered the polar or longitudinal cleavage of the granite, inasmuch as it splits nearly parallel to the felspathic crystals. The transverse or oblique divisions are symmetrical joints, divided as regular as the felspathic prisms constituting the crystalline base. The granites of Spain are divided in the same manner, *i. e.* in lines more or less north and south, and east and west. We observed the same in France at Auvergne.

In Ireland, in the quarries of Golden Hill, the granite is divided by smooth parallel seams into vertical bands, 3, 4, and 5 feet thick, ranging north and south, sometimes leaning slightly to the east, and again to the west, even in the same band in its longitudinal bearing. These vertical tabular masses become naturally separated again into tabular or columnar blocks of a rhomboidal form. The same effect is seen in Glencullen, also on the Dalkey coast, the main splits ranging from north to south, inclining slightly from the perpendicular. Hence the granitic rocks are not rude and shapeless masses, as too commonly supposed; the structure and arrangement of their parts exhibit as great a crystalline order as we observe in the aggregation of crystals on a smaller scale.

The innumerable transitions of the crystalline rocks into the schistose structure, in accordance to their composition and meridional direction, are beautifully displayed in South America, and the same may be observed in the Western Islands of Scotland. The nature and order of these transitions, their respective composition and mechanical changes, have been explained in Chapter VII., page 46.

In these transitions of the crystalline into the slaty structure, we find the granitic, the porphyritic or quartzose bands sometimes terminating into wedge-shaped masses, both horizontally and vertically, as illustrated in Plates VIII. and IX.

The various kinds of structure pass so frequently into each other in the same mass, crystalline and schistose, that it is oftentimes very difficult to observe where the one begins and the other ends. As the crystals become elongated flakes, the rock acquires a proportional degree of fissility, and finally a perfect slaty structure; on this account it is impossible to draw a line of demarcation between the two structures, because the transition is imperceptible. This is the case in all the primary districts.

The varieties of rocks predominating in massive clay-slates, and dividing into rhomboidal blocks, principally belong to the felspathic, this structure being observable from the larger masses to the smaller fragments; and their divisional joints and cleavage planes are more or less in the meridian, or slightly north-east. This compound forms one of the richest variety for the production of copper ore.

CHAPTER XI.

ON THE ORDER OF THE SPLITS, FRACTURES, AND DISLOCATIONS IN THE PRIMARY ROCKS; CROSS COURSES AND HEAVES, INCLUDING THE FAULTS IN THE SUPERINCUMBENT SEDIMENTARY FORMATION.

According to the meridional structure and configuration of the primary rocks, especially the laminated granite, the gneiss, and the schist, together with the cleavage planes, and their ridges, as described above, the general appearance of the surface of the globe may be compared to the grain of a fruit, such, for instance, as an orange, a melon, or a pumpkin, having a grain or structure from pole to pole.

Indeed, when we examine the moon through a telescope, particularly in the clear atmosphere of the tropics, the same appearance is visible. We observe most distinctly numerous luminous rays radiating from the pole facing the south, which are seen diverging towards her equator, some of which extend to the northern edge*.

This meridional force, which produces the elongated crystalline masses, fibrous and laminated structure, and cleaving the consolidated sedimentary beds, must necessarily cause a very considerable polar tension.

Let us, for example, suppose a given area were undergoing an elongation by this internal force, as described in Plate XI. fig. 1; should any part of the crystalline compound not possess sufficient tenacity to allow it to extend, fractures would ensue, and these would take place more or less transversely to the direction of the force; the nature and number of these ruptures would depend on the variable state of the mass. Should they contain subordinate channels of unequal elasticity and variable width, splits would occur longitudinally or diagonally to the grain, according to the direction of the least resistance. That the rocks are elastic, and subject to numerous contortions and undulating movements, capable of being bent and elongated without ruptures, is now so well known as not to require comment.

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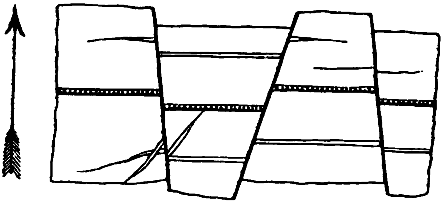
* The bright polar focus of the moon is considered a volcano by the Plutonists, and the radiating rays streams of lava! It requires no ordinary stretch of the imagination to suppose such conditions without causing some awful catastrophes.

We have, therefore, the following series of lines, figs. 2 and 3, as necessary consequences of the polar action permeating the series, viz. north and south splits, and east and west fractures, varying respectively from their true bearing according to local conditions. These again change their original direction owing to the constant action of a similar nature going on in the subordinate bands, thus giving rise to undulations, dislocations, and numerous other disturbances, which destroy in time the continuity in the order of the sedimentary beds. These great lines are well known to miners, quarrymen, slate-men and colliers, in every part of the world; the first as cross-courses or main faults, and the latter as the east and west lodes and cross faults. These two great divisional lines are observed in Chili, Brazils, Peru, New Grenada, Panama, Mexico, North America, England, and on the Continent.

The sides of the great meridional splits are sometimes found beautifully grooved and polished for immense extent. The masses of quartz broken off, or the quartzose face of these divisions occasionally seen in an escarpment, present the appearance of fluted marble. Such grooves and polished surfaces are very common in the primary series, and are sometimes attributed to the effects of ice or avalanches, &c. brought down from higher regions along the valleys. However, such ideas have been formed as loosely as those which attribute hornblende veins and other black rocks to volcanic eruptions. We do find occasionally coarse grooved sides in deep ravines, which have been produced by the friction or attrition of masses of matter carried down; but these effects are as different from those polished striæ seen on, and *within*, primary and other rocks as the sedimentary planes are to cleavage planes. The sides of the great flookan cross-courses, main faults, or the great meridional splits, are invariably grooved and polished, from the effects of the longitudinal movements of the parallel masses, which cause heaves or dislocations. The striated polished sides of the polar splits of South America vary from 10° to 30° from the horizon, rising towards the north, and are seen not only along the sides of extensive ridges, but also for many fathoms in depth within the primary series.

Similar meridional splits with polished and grooved sides are seen in Mexico, in the United States (in the coal-beds of Blackheath), and also in Cornwall and other places in England. These primary splits and fractures have broken the sedimentary beds into various fragments of somewhat rhomboidal form, according to the obliquity of the tension and resulting splits and fractures, as shown in Plate VI.

The splits and fractures, and the crystalline mass being in continual motion by the constant action of the subterranean molecular force, produce great disorder in the general structure, and cause dislocations (called *heaves* by the miners). These are the effects of the horizontal or diagonal motion of the individual strips of rocks between the splits from their original position. The great *heaves* are produced by the northward action of the rocks between the polar splits, as shown in the following sketch.



These dislocations have created great discussions, and have caused very opposite opinions, owing principally to the impossibility of restoring the continuity of *all* the fractures on both sides of the splits. A very little reflection must show that such an agreement in *all* the fractures could not be expected. In the first place, the ruptures across the splits would necessarily take place in the direction of the least resistance, be that in a direct line or not; it does not follow that it should be straight across the split. If, again, we consider that the rocks are exposed to the continual action of the polar force, and therefore subject to a slow movement northward, there would necessarily be fractures taking place periodically in the same masses, *i. e.* when the "heaves" are only 1, 10, 20, 30, 50 fathoms; how then would it be possible to restore the continuity of the whole series of fractures? It is well known, and can be proved, that the fractures have occurred and have become forced open and filled at different periods. It is like attempting to refit pieces of ice, after having been broken and subjected to repeated movements and undulations, and reunited again by repeated freezing, as to try to restore dislocated masses of rocks in the primary base.

When we consider the semifluid nature of the masses, and their permitting a continual molecular action through their pores in the meridian direction, like the current of sap in a living tree, and also supplied by other elements by means of the conducting fissures, we need not be surprised that the sides of the fractures cannot always be refitted; their ruptured parts are altered by the chemical action in a very short time; the south sides of which are often seen penetrating into the northern by a new cleavage formed subsequently to the filling of the cracks, as represented in Plate IX.

Miners are well aware that the sides of veins often bulge out in defiance of all mechanical resistance; it requires a considerable practical skill to keep them open to extract the mineral, particularly in very wet ground. When the *splits* happen to be in a *north-west direction*, the masses of rocks on the *western side* are generally forced *northward* more than those on the eastern side: if the *splits* be towards the *north-east*, the *contrary effect* takes place; that is, in real *heaves*, because a great number are called "heaves" that are only apparent. See

Fig. 1.

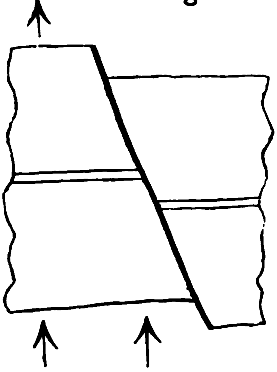
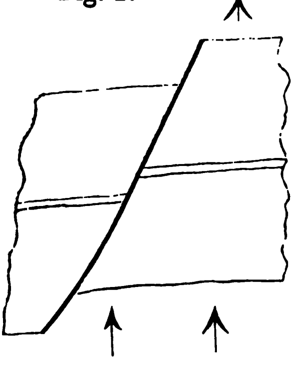


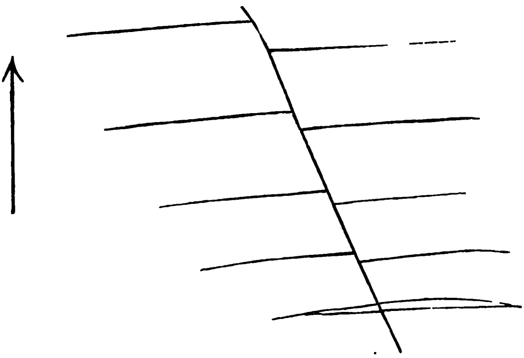
Fig. 2.



sketches. In Cornwall the majority of the *splits* are north-west, as described above, in fig. 1; consequently all the principal "*heaves*" of the country are to the right, the western masses having shifted northward more than the eastern. The red sandstone and carbonaceous series, intersected by a split near Tiverton in Devon, has been shifted northward on the western side nearly half a mile. In the vicinity of Tavistock the same kind of "heaves" are seen in the Devon Consols, &c. There is a great northward "heave" near Gwennap, produced by the great cross course traversing the North Downs; and also several in the Camborne district. See Plates XVI., XVII. The direction of the "heaves" is generally expressed by *right* and *left*, because the same expression serves on approaching them on either side. Some suppose that the nature of "heaves" depends on the direction and inclination of the mineral veins or transverse fractures; but this is a mistake: the movements of the masses are quite independent of the lodes or fissures, and would be the same had they not existed. Nor does it follow that the dislocated veins should be always "heaved" on the side of the obtuse angle, as generally supposed, because this depends on the angle of the fracture itself.

The cause of the above order in the dislocated masses is made manifest when we examine the nature of the mechanical disturbance. Admitting the magnetic force to act in the meridian, the direction of the *oblique splits* destroys the parallelism or uniformity of the polar forces; consequently the masses presenting the largest transverse base to the south will be propelled northward at a greater force than those terminating in pointed angles in that direction.

With regard to ruptures produced by tension, they are of daily occurrence; and although those who live on the surface are unconscious of such subterranean disturbances, yet the miner who spends the greatest part of his life in the subterranean laboratory of nature is well acquainted with such phænomena. On one occasion, in the Boston Vein, Peak Forest, the solid rock was rent on the south side in a vertical direction to the depth of thirty-six yards below the place where the miners stood, and sixteen yards above them, and accompanied by a report equal to that of a cannon: one part of the rent was wide enough to admit a man's body. Sudden concussions and internal sounds are often heard by miners in all countries, thus causing much fear and superstitious ideas, well known amongst the German and South American miners. All wet grounds in rocks containing bands of hornblende, talco-magnesia, carbonate of lime, and impregnated with arsenico-sulphuretted minerals, are very active, and cause much expense and trouble in timbering. The great meridional splits are generally so full of water that the lines of springs thrown out along their direction afford considerable facilities in tracing them. Hence, by means of the porosity of rocks, and of fissures that traverse them, these meridional conductors, or irrigators, bring in water with a variety of substances in solution, and keep the rocks in a state of saturation. These conditions are highly favourable to the transmission of minerals from one place to another by electro-polar action; consequently, when the crystalline rocks are much fractured, a variety of effects must take place both mechanically and chemically. We have, therefore, in fissures and vacuities receptacles for numerous mineral productions, the character and quantity of which depending upon the *conditions* under which they may exist, to be explained in the next chapter. In a series of parallel fissures (E. and W.) intersected by a diagonal split, we generally find the "heaves" or dislocations to the north much greater than to the south. See diagram.



This may be seen in the Consolidated Mines and Camborne district, and also near Tavistock. There is scarcely any rich copper mine without being intersected by N. and S. courses, and the more numerous the more productive, and *vice versâ*. Indeed, the circumscribed nature of the mineral parts of the fissures or lodes, together with that of the aggregated mineralized masses conforming to the angle of the cross-courses, and the structure of the bounding rocks, and the influence the impermeable meridional splits and conducting N. and S. veins have in the accumulation of the useful minerals, are well exemplified in the great mines of Cornwall and Devon, and show most distinctly how essential it is to study these natural laws to ensure the success of the explorations. The great "cross-courses" in the parishes of Gwennap and Tavistock may be traced on the surface by the range of large and productive mines, which lying more or less in a N. and S. direction, indicate their intersection and enrichment by the meridional joints. The same may be observed at Redruth and Camborne; hence the old saying of the miner, "the great cross-courses are the parents of all the ores." Before we proceed with the chapter on mineral veins, we shall trace the effects of the splits and ruptures on the superincumbent sedimentary masses, more especially in coal-fields.

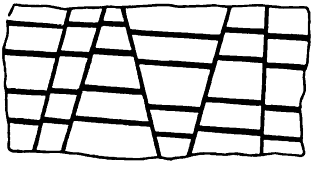
CHAPTER XII.

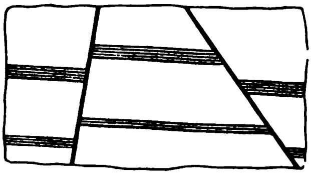
FAULTS IN COAL SEAMS.

We have already alluded to the effects of cleavage, *i. e.* that all the sedimentary rocks are liable to be cleaved by the primary base; this is particularly the case with coal, which greatly facilitates the extraction of the coal-seams. This is well displayed in the coal-fields of Virginia, owing to the proximity of the beds to the gneiss and other schistose rocks below. Parallel to the stratification of the seams are first, the partings, analogous to the exfoliated subdivisions of rocks; intersecting these, in a more or less vertical position, are the polar cleavages; these last separations are sometimes called "backs" or "bright heads," from the coals separating at these cleavage planes like slates, but with clean and highly-polished surfaces, except when, as it often happens, the complanatory lustre is covered with a rusty-looking scale, or with the well-known sparry concretion, consisting frequently of carbonate of lime, and sometimes carbonate of iron, also magnesia, according to the character of the inferior basin, these substances being derived therefrom by infiltration of the minerals held in solution. Besides these, there are fissures passing almost vertically, nearly at right angles to the planes of cleavage, being fractured divisions, and are appropriately denominated "cutters." Indeed, these geometrical divisions are similar to those observed in fine roofing-slate quarries, and consequently, by means of this compound system of natural series of lines, the coal, like the blocks of slate-rocks, is often broken, or separated from the seam in parallelopipedal masses.

The "slips" and "faults," although sometimes but mere joints, cause, nevertheless, great dislocations in the stratification, like the "flookans" in the primary base already described. A vertical dyke, running at right angles to the series, only disjoints the beds, neither effects their elevation nor longitudinal position, being similar in this respect to the same kind of cross-courses in the crystalline rocks. When the polar joints, or great main faults, are very *oblique*, a vertical dislocation will take place, and the masses will be elevated and depressed, and press and slide on each other until the equilibrium of the pressure on the soft base below is restored.

The general condition of these dislocations will be seen on reference to the following diagrams.





The greater the acuteness of the angle of the fault, the greater is the dislocation. If the angle formed is obtuse, or in other words, if the observer looks at the dislocating joints from the floor of the opposite bed, the effect will appear as an upthrow. When the angle is 90°, vertical dislocation seldom takes place. We shall now explain the cause of the order, or the law, of these disturbances. As the carboniferous strata rest on a semi-fluid base, such as beds of clay and moist carbonate of lime, and rocks in the usual high degree of saturation, the main polar divisions, if obliquely cut, will disturb the uniformity of the pressure, consequently the isolated masses will gradually subside or elevate according to the angle in which the masses are divided by the "faults." The most simple and frequent cases of such dislocations are represented below. Let us consider what would be the consequence of the oblique subdivisions of the coal seams in fig. 1 resting on a soft and semi-aqueous base. According to the laws of statics, the pressure will increase as the lower area of the masses becomes less than the upper, and *vice*

Fig. 1. *Angular Splits and Fractures.*

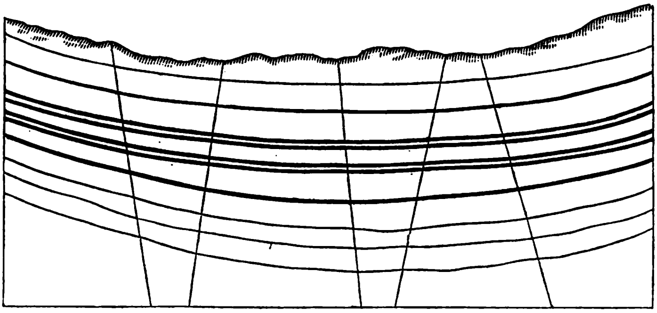
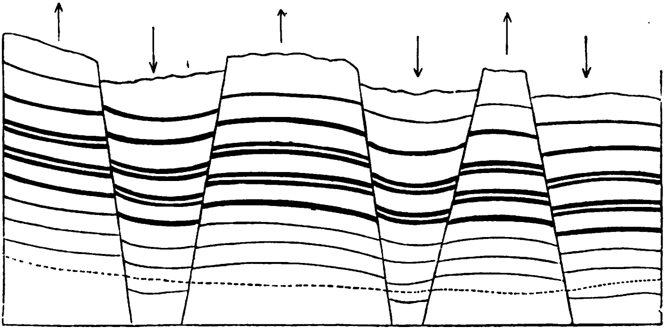


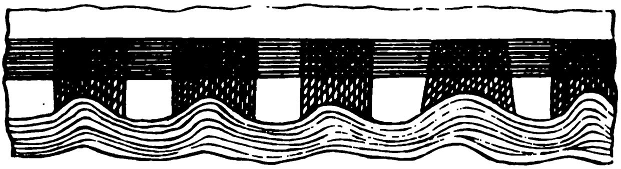
Fig. 2. *Subsidence and Elevation of the separate parts according to the angles of the Faults.*



Semi-fluid base.

versâ: the weight divided by the area will give the amount of each, therefore the *wedges* will *sink* and the *parts between them rise* to restore the uniformity of the pressure on the soft base, as illustrated in fig. 2. The planes of these joints, and also the oblique transverse fractures caused by their movements, are often seen with a polished striæ from the rubbing or sliding of the separated masses on each other; and as the direction of the action must necessarily depend on local conditions, being sometimes vertical, horizontal, or diagonal, the polished grooves are not always parallel, but often curved and in various undulations.

The above various effects are well shown in almost all workings carried on in the coal-measures. We sometimes find the roofs and pavement gradually unite, leaving not a trace of coal behind, the clay or softer shale disappearing also at the same time, as if they were squeezed out by the weight of the superincumbent strata; the pressure of which having been increased by the angular separation. This is well exemplified in what are called creeps.

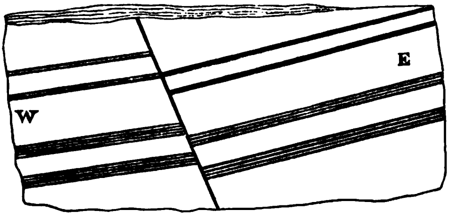


When the pavement or bottom stratum under the coal happens to be soft, being commonly fire-clay and shale, and the pillars somewhat small, the pillars will sink and the floor rise as described in the figure; to avoid these effects we are obliged to form large pillars. Sometimes the sedimentary beds are separated vertically upwards of 1000 feet, yet the masses of the uplifted and depressed strata do not present such irregularities on the surface as to indicate these disturbances. These actions have been going on so extremely slow during many ages as to allow sufficient time for the superficial parts to be modified at the same rate, obliterating thereby all irregularities on the surface by atmospheric and various other causes. It was supposed that even these "faults" were the result of violent mechanical convulsions produced by volcanoes, but such notions have arisen from the want of a more practical knowledge of the general character and order observed in the disturbed strata. "Faults" are often filled with clay and various other substances from the base below, or from the softer interstratified seams by means of the pressure above described; these substances render the "faults" impermeable, and, consequently, the water percolating in each mass is retained by these natural dams, which is of great advantage to the independent workings of coal districts. From this cause the coal on one side of a fault is often different from that on the other side; sometimes losing its bituminous quality and becoming impregnated with other elements. Occasionally a perfect transition may be observed from anthracite to bituminous coal, the modifying cause being from the former to the latter.

The theoretical geologists have an idea that the hornblende seams which are interstratified in the carboniferous beds of England, were forced into their present position in an incandescent state, from their imaginary igneous nucleus, and they have endeavoured to point out the centres of eruption or focus of volcanic force. Several such centres of eruption have been long pointed out in the Wolverhampton district; but, like a number of other such vague and unfounded notions, they only serve to amuse the uninitiated, and are scarcely noticed by practical men of science. The masses of green rock called "trap," at Pouk Hill, the Nechells, and other localities in the Wolverhampton district, are not owing to these points being centres of eruption, but simply to the intrusion of semiaqueous substances by cross-courses and the bed of greenstone (which had been forced in as hornblendic clay) throwing off branches from its upper surface: the under part of the above bed of trap-rock rests uniformly on the seams below, and the coal underneath it is found in a comparatively undisturbed state, thus showing that the disturbance in the district beyond the main faults is confined principally to the upper part of the series. This trap or hornblende seam, which has been gradually forced into the sedimentary divisions from the main "faults," is always moist, and frequently found as soft as clay. The degree of moistness indicates the degree of disturbances; and the beds in contact are found fractured, and saturated with mineral solutions, and the cracks filled with calcareous, siliceous or hornblendic matter, proceeding from the trap-bed. As the upper beds present the least resistance to the forcing and swelling power of the intrusive semi-aqueous seam, the fractures and veins are formed in the upper portion, and they bear the same analogy or relation to it as the quartz veins do in the slaty rocks. These veins and branches are constantly formed by the squeezing of the separated dislocated masses, similar to what may be seen in a bed of soft clay confined and covered by a layer of stones or bricks; the clay is forced up between the joints according to the amount of pressure; and this is what is termed centres of volcanic eruptions in the coal formations. When the coal happens to be in contact with the above active moist rocks, it is more or less impregnated with mineral, especially the peroxide of iron, and therefore, when dry, becomes somewhat reddish, vulgarly called "burnt coal;" but igneous fusion has had no more to do with this change than with the "gases," or with any other slow chemical saturation by the humid way. One of the most common effects of heat upon limestone, is to deprive it of its carbonic acid and reduce it into white powder. Chalk, when intersected by veins of any substance containing carbonic acid, becomes partially converted into marble by the absorption of the acid. However, like all theories suggested by eminent men, and made fashionable, they are by a little philosophical coaxing applied to account for all phænomena. The assumed igneous theory appears by its supporters to possess extraordinary properties, remaining unaffected *in* water as well as in air, hot or *cold,* according to circumstances; capable of converting limestone into lime or lime into limestone, coal into coke or coke into coal, as they may feel disposed to apply it, and totally uncontrolled by any fixed principles or known laws of heat. Such is also the case with the glacial theory; all polished striæ is attributed to its effects, hence an icy epoch is assumed in the history of the sedimentary series. These kind of hypotheses are most arbitrarily founded on very loose observations, and not only most irregularly applied, but generally so irreconcileable to the observed phænomena as to render the science of geology as yet unacceptable to practical men.

To return to the subject of the chapter on the effects of faults, we find that not only is the water separated and retained within given areas, but also the subterranean gases, the carburetted and sulphuretted hydrogen, the local accumulation of which is much influenced by the angular position of the "faults," dip of the beds, and the planes of cleavage.

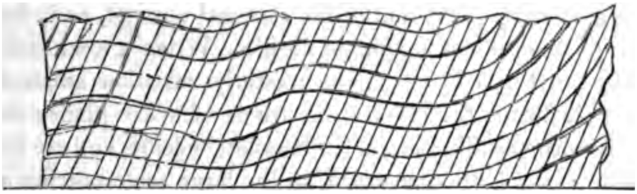
In working near the crop of the coal, we are seldom troubled with gas, and a very indifferent system of ventilation may be sufficient for the purpose; but in the dip on the other side of a fault the gas accumulates so much as to render it no easy matter to effect a perfect ventilation and prevent the gas remaining stagnant in the upper recesses. I know a colliery on the east side of a fault, where the coal seams rise towards the surface; the colliers have been working for upwards of fifty years without the least obstruction from fire-damp, with only an ordinary means of ventilation; whereas, on the west side of the fault, the seams are highly charged with carburetted hydrogen, being, as it were, retained by the fault. On the east side ventilation is effected with the greatest facility; but on the west side of the fault, without the aid of a very judicious method for the extraction or the escape of the gas as it evolves, the consequences would be very serious. See the annexed section. In a word, the local accumulation of the gases depends on the angular position of the beds, the polar cleavage and faults, and the impermeability of the superior strata.



CHAPTER XIII.

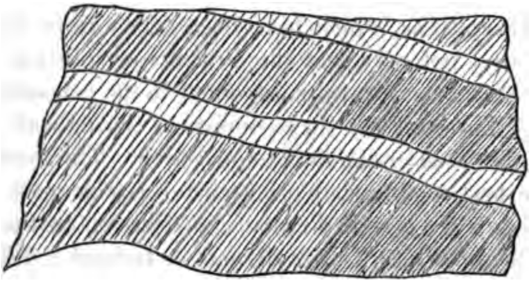
ROOFING-SLATE FORMATIONS.

Although slate quarries are so common, yet there is no subject more interesting and instructive in questions connected with the semi-crystallization of consolidated sedimentary rocks, and geological dynamics, as the study of these formations; notwithstanding the facilities presented to investigate their character, the phænomena they exhibit, and the true nature of their structure, they are scarcely known to the scientific world. Many imagine that the planes of cleavage are the same as the planes of the sedimentary bedding, and that their present high angle, or vertical position, is owing to the stratification having been lifted up on edge by subterranean forces. The sections in Plates VII., VIII. and IX., which have been taken from nature, will show at once, not only that the cleavage or splitting planes of the rocks have been formed subsequent to the consolidation, inasmuch as they intersect them uniformly through all their undulations, but also in one definite direction. The average bearing of the best roofing-slate cleavage is a few degrees to the E. of N., which is the case in Germany, in Nassau, on the banks of the Moselle, in Wales, Cornwall, and in Ireland. Whenever a slaty formation is thrown from this angular position by any intrusive crystallizing rocks, the uniformity of grain and tenacity become partially deteriorated or even destroyed, and quartz veins or hornblende gradually form by the contortion and fractures, as shown in Plate X. taken in North Wales. In the Welsh slate rocks, even after the sedimentary planes have been completely obliterated, we detect the old bedding by various shades or tints, as shown in the following cut. These effects, as already stated, do not apply solely to mere quarries, but also to extensive chains of mountains in both continents. The best slate rocks are separated from the quarries in geometrical figures approaching that of felspathic crystals. At the base of these great slaty rocks, we find in many places, both on the continent and also in North Wales south of Snowdon, the gneiss, primary schist, hornblende and granular granitic bands, in their usual structural bearing,



corresponding to that illustrated in Plate VII., section of the Andes, and thus showing not only their contiguity, but the cause of the cleavage of the superincumbent sedimentary bedding; the angle and bearing being always conformable.

We frequently observe a similar effect having been produced in veins of porphyries, and, subsequent to their consolidation, in slaty rocks, as shown in the annexed diagram.



When the cleavage planes and the old sedimentary seams conform, they produce strong slates and present fine phases of crystalline flakes; when at right angles to each other, the slates are somewhat brittle and do not break into long splinters, but possess a fibrous texture.

In a previous chapter we dwelt on the phænomena of order observable in the polar cleavage, and also alluded to the fact that the subterranean current passing through the cleavage planes causes a westerly deflection of the external current, as indicated by the position of the magnetic needle. When a weak solution like sea-water is employed, the westerly variation amounts to about 10°; hence the polar structure or cleavage planes do not coincide with the direction of the magnetic needle, and are found, as already stated, on an average, on the large scale bearing a few degrees E. of magnetic north, but in various undulations. If, in our experiments, we wish to retain the natural position of the magnetic needle, whilst within the influence of an active but weak battery employed to produce cleavage in a mass of clay, it will be necessary to place the apparatus in such a position as will make the internal current of the battery from pole to pole to run from S.W. to N.E., that is, in fact, parallel to the terrestrial cleavage.

On this arc of variation between the internal and external magnetic currents, depends the principle of the electro-telegraph. By means of experiments we can also produce the elongated N. and S. veins and the E. and W. fractures. We also observe a general tendency of the liquid and the soft mass of clay to press on the oxidating pole of the battery. If we divide the mass of clay obliquely from one side of the copper to the opposite side of the zinc plate, by means of a fine impermeable substance, so as to represent a diagonal split, a dislocation is produced in the transverse lines, and the cleavage slightly twisted; the triangular mass with the greatest base on the diverging or negative pole, being forced and compressed against the zinc plate to a greater degree than the opposite mass.

In order to show this linear polar effect more distinctly and quickly, and how fluids propagate polarity in the molecular compounds, let a few filaments of tinfoil be placed on the surface of water in an oblong trough, and dip into each end wires from the two extremities of an active battery, the metallic ingredients will immediately acquire polarity and arrange themselves in a linear direction corresponding to that of cleavage planes and the fibrous structure of the rocks from pole to pole. Various solutions of metallic substances allowed to crystallize very slowly between the poles, exhibit the same phænomena, and identical to that observed in the great subterranean terrestrial battery, as already explained*.

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* We have already insisted that cleavage planes are formed *in the direction of the currents from pole to pole*. Experiments have been made with the view of imitating these crystalline planes, by placing a mass of clay between the poles of a battery, and it has been supposed that the small transverse *fissures* produced by the tension represent the phænomenon of cleavage. A very slight examination will show the distinction between them. Those who may feel disposed to imitate real polar laminæ must furnish each pole with a piece of laminated rock; without this preparation cleavage planes cannot be produced by artificial means. A mass of clay jammed between the walls in a vein of fracture will be cleaved across by the natural magnetic currents in a very few years. It is this constant cleaving action which is the cause of veins becoming obliterated, as represented in Plate IX.

CHAPTER XIV.

MINERAL VEINS, THEIR FORMATION, AND THE GENERAL CHARACTER OF THEIR CONTENTS.

Besides the conflicting opinions respecting the origin of mineral veins, much confusion has also arisen from the very loose signification applied by miners to the terms *veins* or *lodes*. Such terms are often given to almost any kind of mineral deposit which affords a foundation for mining operations, however widely it may differ in character from the definition of these terms in the ordinary sense in which they are taken. In fact, the mere detection of a crystal of mineral in a rock, and more especially flakes and small flat nodules of minerals enclosed in the cleavage of the slaty rocks, is sufficient to cause some persons to conclude that there *must* be a lode in the vicinity to produce such minerals. They suppose minerals can only come from veins or lodes: and again, when small masses of ore are discovered in slates, however insignificant they may be, it is considered that there must be not only lodes, but unequivocal indications of richness in depth.

These notions are encouraged by mining jobbers, and are the means of a deceitful system of mining being carried on at the expense of the unwary capitalists, destructive alike to the interest of the tenant and landlord, as well as to the injury of legitimate mining.

It has been already stated that the rock is the parent of the mineral, *i. e.* that it is the soil as it were out of which the minerals grow, with the exception of what may be brought in addition by aqueous conductors; and from the appearance of the rock, in composition and texture, or internal structure, we can determine its probable production. The manner in which the metallic or mineral products become developed depends on mechanical causes, and the internal compactness and aggregation of the crystalline compound.

We have already shown how metals are produced and liberated from rocks by decomposition, and shall now explain the formation of sulphuretted ores in the fissures of rocks from mere joints to the magnitude of great lodes.

Sulphurets were formerly considered as scarcely explicable in the wet way, sulphur being supposed insoluble in water; but we find innumerable springs holding sulphur in solution, such as sulphuretted hydrogen, as already explained. All metals are held in solution in a weak alkaline mixture and in different compounds. Carbonate of lead is soluble in alkali and lime, and precipitable therefrom by sulphuretted hydrogen. It has a greater affinity for lime than for any other earths; hence limestone formations contain lead in preference to other metals; marshes are also usually more productive of masses of lead ore than the higher and drier parts of the rock. The carbonate of lime not only accompanies galena or sulphuret of lead in the limestone rocks, but also very frequently in the clay-slate and porphyritic formations, as a matrix of the ore.

The most pure metals, when sufficiently divided, are soluble in water; and it has been shown that silver, as well as mercury, lead and copper, &c., are taken up by water and deposited on the surface of rifts, as in the Christiania mines in Norway, in Peru, and in a number of other mining districts. When, therefore, water impregnated with sulphur meets with the same element charged with metals, permeating the joints and pores of the rocks, precipitation takes place and forms a compound in accordance with the laws of affinity; but this formation of sulphurets is again subject to be dissolved and dispersed by an alkaline reaction, as proved in many instances.

In Peru and Chili pieces of wood that for years had been left standing in old mines have been found partially converted into siliceous fossils, and others again covered only with calcareous spar, metallic silver, grey and red silver ores, and fine crystals of iron pyrites, by solutions from metalliferous rocks. New crystals of pyrites, both iron and copper, have been found in the old decomposed heaps of pyritous refuse in South America, formed during decomposition.

Arsenico-sulphuretted waters have been detected, not only in foreign countries, but also in Cornwall and Devon. Antimony has been found in a state of solution in the mine of Santa Cruz de Mudela in Spain, and in many mines of the Americas. The sides or walls of the old mine at Mausterappel have been found covered over with natural cinnabar that had transuded from the rock subsequently to the stopping of the mine. I have seen similar formations in old workings in New Granada, and in an excavation at such an altitude in the rock as would not admit of its being filled with water; yet a thick crop, or an efflorescence of black ferruginous crystals, had been formed on the walls (analogous to the formation of nitrates on the wall of an old cellar), containing a large proportion of fine grains of gold. At Wolfclough mine, in the county of Durham, which was closed for more than twenty years, and opened again, needles of white lead ore were observed projecting from the sides of the veins, more than two inches in length, being in fact equal to a vein two inches thick, formed during twenty years.

To avoid confusion, and to render the principles which are here maintained respecting the origin of mineral veins intelligible and practically useful, we shall distinguish the variety of veins or lodes, and illustrate their respective characters by diagrams. Plate XIV.

Fig. 1 is a section of an ordinary lode, being a fissure or a fracture, obliquely, or at right angles to the pores, grain, or cleavage of the rock, in which minerals are found in masses according to the metalliferous nature of the "country," and running more or less E. and W.

Fig. 2 exhibits a split vein, or a lode enclosed in the grain or cleavage of the rock, and running more or less N. and S. This variety is more favourable for lead and silver ores than the former, and is unfavourable for copper.

Fig. 3 are cross courses. These are aqueous conductors, or great irrigators of the metalliferous rocks, without which the lodes are seldom productive of large masses of ores, and more especially copper. The greater the amount of disturbances the more favourable for the accumulation of minerals, and *vice versâ*.

Fig. 4 are oblique joints between a split and a fracture ("caunter"), favouring in many instances the accumulation of minerals; and when N.W. productive lodes.

Fig. 5. Seams, or ore forced into the joints of the beds of the rocks, sometimes called "floors,"—a very unfavourable position for the accumulation of minerals, and more especially when the beds dip to the south.

After the tension has produced the slightest fracture, and caused a break in the continuity of the internal pores, a stoppage of the aqueous current takes place and a crystallizing action commences. Sulphuretted ores are always subject to crystallize; these, with the crystallization of quartz and other substances, exert a force indefinitely strong, and will force a whole mountain forward. Even water on the point of crystallizing into ice, bursts metallic vessels and displaces immense masses of rocks from *situ* in the snowy region. In the formation of veins in the primary siliceous rocks quartz takes the lead, and commences the opening and filling of the vein.

The veins found in the calcareous rocks are generally first filled with matrix found in the series, such as carbonate of lime and baryta, and the minerals subsequently brought in, and accumulate in strings or separate bands in the middle of the lode, or dispersed throughout the gangue.

The sulphuretted metals thus formed in veins, accumulate or gradually augment in different ways; they may be conveyed in their sulphuretted state through the pores of the rocks to the fractures, and therein crystallize (being the ordinary mode in which they are formed), and also by the metallic solutions traversing the pores meeting with sulphuretted hydrogen in the fractures, supplied from the cross-courses, and thus become mineralized. The cross-courses not only supply elements to favour chemical activity, but divide also the district into bands, confining the mineral within certain limits, thus enriching one part at the expense of another portion of the rocks.

CHAPTER XV.

THE FILLING OF JOINTS, FRACTURES, CAVITIES, ETC. BY THE SUBSTANCES PERMEATING THE ROCKS.

In looking at the sulphuretted minerals which have replaced organic remains in compact argillaceous and calcareous sedimentary rocks, the reader may be prepared to expect not only a similar action, but one of greater amount in the fundamental crystalline series. When we find mollusc and spirifera shells formed of sulphuret of copper, iron and lead, in their exact form, we cannot avoid coming to the conclusion that these mineral substances must have been introduced in solution into the cavities left by the decomposition and disappearance of the shells. These effects are so common, not only in the Americas and on the Continent, but in many parts of England, in the chalk, lias and mountain limestone, as not to require reference to any particular locality. We find also sulphuret of iron and of lead in the minute fractures of fossil wood and bones in the sedimentary calcareous rocks. Even the carbonate of lime of many fossil shells does not always appear to be that of the original, but to have been infiltrated into cavities left upon the disappearance of the matter of the actual shell.

Again, in the crystals of felspar, decomposed in the body of a rock in a homogeneous kind of porphyry (Elvan), the original substance of the crystals are frequently removed, and are replaced by peroxide of tin or pyrites, showing most distinctly that mineral matter in solution permeates the pores of the hardest rocks in the absence of veins or joints. In a word, looking broadly into the general character of our rocks composing the external part of our globe, both primary and secondary, we find them a compound of all the known elements in a semi-aqueous state, and, as a necessary consequence, have always a tendency to fill all cavities, joints and fractures, with mineral matter in solution, which crystallizes by degrees therein, in accordance to the laws that govern the different compounds.

According to the preceding observations, we would naturally conclude that all fissures, be they joints or fractures, would partake more or less of the mineral character of the rocks so divided or broken; that the substances principally filling the joints and fractures in limestones would be calcareous, while those amid siliceous rocks would be quartzose, and in hornblendic rocks, veins of greenstone or basalt, as is usually the fact. However, occasional variations do take place; for instance, in a compound of carbonate and silicate of lime, we sometimes observe quartz veins, and on the contrary we find veins of carbonate of lime enclosed in siliceous formations. Indeed nearly all the primary limestone is so situated, and is usually found in great bands enclosed in granite and gneiss.

The filling of cavities and small fissures in crystalline and other rocks by carbonate of lime is very common, even when calcareous rocks do not constitute any large proportion of the bordering mass. The ready solubility of the carbonate of lime, when saturated with an excess of carbonic acid, occasions the passage of the former substance from calcareous rocks into the vesicles of others; and if not again decomposed and removed, it would prevent the deposit of other substances passing in solution through them. Sometimes the decomposition of the felspar in porphyry will liberate a large proportion of lime, which may issue out and be deposited on the surface of another rock, or be precipitated within its cavities, without the parent rock indicating to an ordinary observer any calcareous properties. This is commonly seen in the western chain of the Andes*.

When we reflect on the composition of the water which may insinuate itself into a fresh fracture, intersecting series of crystalline rocks of variable composition, all in a moist state, saturated and composed of elements susceptible of generating active chemical actions, when partially mixed in solution or coming in contact, the question becomes much more complicated than the mere permeation or infiltration of a simple substance, and easily accounts for the great variety of minerals we sometimes find crystallized together in our mines.

Let us take as an example the following variety of rocks which mineral veins commonly intersect, viz. the granitic, hornblendic, schorlaceous, felspathic, and consider what must take place in the fractures, when the formation is traversed by north and south cross-courses, effecting a linear aqueous communication with the internal moist rocks and sea-water. Before we can fairly appreciate the chemical action during the decomposition that will ensue, it is necessary to reflect well on their respective composition.

Common granite is composed of silica, alumina, potash, and often soda and lime, magnesia, oxide of iron, oxide of manganese, fluoric, carbonic and other acids, and traces of minerals partially disseminated.

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* Substances crystallizing from solutions are more readily formed in rocks of the same character than in others.

Hornblendic,—silica, alumina, lime and magnesia, protoxide of iron and manganese, and acids in a different proportion to the granite.

Schorl rock,—silica, alumina, potash, soda, lime, magnesia, iron, manganese, boracic and other acids, with a partial dissemination of the peroxide of tin.

The *felspathic argillaceous* (killas or granitic clay-slate),—a homogeneous compound of the elements of the granite partially decomposed, with a large proportion of alkali, and an excess of mineral solutions.

The above rocks, in consequence of their moist state, form a transition into each other at their junction, sometimes in meridional bands, and also when lapping on the granite. The great *cross-courses*, or meridional splits, irrigate the whole series with saline solutions from the sea, and thus render the mineral compound in a state of chemical activity.

The *sea-water* is composed of chloride of sodium, sulphate of soda, muriate of lime and magnesia, sulphuric, phosphoric and many other acids, and frequently traces of metallic solutions.

We have to regard not only the combination and mixture of such elements when introduced into the fractures, but also the effects of the constant tension of the electro-magnetic power permeating the whole mass, causing mechanical disturbances and reactions, and double and treble decompositions amongst the various compounds. A certain degree of heat must be produced when the sulphuric acid comes in contact with infiltrated fresh water, or when the acids attack the bases; the water will be decomposed and sulphuretted hydrogen will be formed, and this will act as a strong metallic solvent, and in absorbing the latter sulphurets will be formed; the hydrogen in evolving towards the surface would decompose the upper part and reduce the minerals into oxides (gossans), thus rendering the mineral veins visible on the surface. A reaction may again take place which may reduce the minerals from sulphurets into carbonates, muriates, oxides and metals. Should sulphurets of copper, silver, iron, &c. become in contact with a solution of common salt and a weak solution of sulphuric acid, the water will be decomposed, and the iron and the salt will be attacked by the acid and be reduced into sulphates of soda and iron. The sulphate of iron will dissolve the silver, and the chlorine will then convert the silver and copper into chlorides, and both of which may be deposited in joints or vacuities in that state, and remain so until attacked again by agents which may change them into carbonates, oxides or metals.

The sulphuret of copper, when formed in the neighbourhood of carbonate of lime, is subject to be decomposed into a green carbonate, the lime is precipitated and partially changed into a sulphate. Thus the "greens" of the miner are commonly formed, and may be seen on old white-washed walls, or infiltrating through rocks containing carbonic acid, or decomposed vegetable matter. All chemical actions evolving gases tend to ascend; thus crystals radiate or form at right angles to the surface, and grow out, as it were, like vegetation, the metals efflorescing in an arborescent form. There is always an upward action in the mineral as in the vegetable kingdom; in short, all substances that liberate gas exhibit this effect. Hence the grand region of natural chemical operations and the production of minerals are brought within our reach, supplying the wants of all generations, by slow and apparently feeble actions, which do not produce any material injurious effects on the vegetable kingdom, nor yet on the habitation of man, beyond those few local disturbances occasioned by a too powerful action of the elements.

The cross-courses, generally speaking, supply the active mineralizing agents, such as the sulphuric, carbonic and other acids; the rocks provide the minerals and the alkalies. The compounds are formed only at the points, where the metallic sap oozes out. Thus a rock which may be very favourable for the formation of ore, may not indicate the presence of the mineral by impregnation or in a state of aqueous dissemination. Again, it often happens that a compound is formed by the aid of several elements brought together from different points, similar to the gradual formation of the trunk of a tree; the distinct elements of which are brought from the soil by the conducting power of the roots. The seed, with its active principle being the fixed point, causes the first action on the elements surrounding its immediate neighbourhood;—the plant increases in bulk, and becomes more powerful until the required elements are abstracted from the soil*. This deficiency becomes by rain or aqueous saturation replenished, and the tree increases in magnitude by the constant supply: and such are the local effects of mineral crystallization.

The formation of a crystal will cause a local attraction towards it of similar elements; and however slow this process of metalliferous aggregation may appear at first, yet the decomposition and the crystallization of the separate elements become by degrees very powerful, from their respective cohesive forces, and these forces increase in energy proportionably to the increased bulk. The different elements after separation will cause new combinations and arrangements till they arrive at a comparative quiescent state, the whole of the contents of the bounding rock being abstracted prevents further metalliferous accumulation. This is the case with many of our great mines; the rocks in which the rich veins are enclosed are like exhausted soils, having all the nutritious elements drawn out. Again, the reason why cross-courses are so important for the enrichment of a district, and yet poor in themselves, is evident, inasmuch as they are only the irrigating channels, bringing in active chemical agents to combine with the elements of the rocks to form the minerals; and as they are constantly in a state of activity, filled with strong solvents, no important mineral crystallization can take place in them under such conditions.

The greater the degree of metallic saturation, especially iron and arsenic, exposed to the permeation of acids and salts, the greater is the degree of mechanical and chemical disturbances, and the heat produced; and also the local accumulation of minerals. These frequently give rise to mineral and thermal springs, and some substances would be deposited, whilst others would be carried away in solution. A mineral may lose its argentiferous contents by an excess of sulphate of iron dissolving the silver, and this metal may be precipitated in another joint on a barren rock, or any other substance, and thus form a vein of silver in the neighbourhood of a copper lode*. The power of the ordinary spring-water to dissolve the hardest rocks is much greater than is generally supposed. Small streams in the course of time perforate and groove basaltic rocks, as is frequently observed in the ravines of South America.

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* An illustration of the great mechanical power produced by a seed growing into a tree in the crevice of a strong wall, may be obtained in the ruins of old abbeys. The strongest walls, and even rocks, have been disturbed and broken by the growth of trees.

All substances become dissolved in the course of time in the ordinary temperature of the subterranean liquids. Sulphate of baryta, a substance very common in lead mines, has been termed insoluble, although found in such a state as to leave no doubt of its being deposited from solutions.

In some districts on the continent (Prussia) we find the indications such as to warrant the supposition that the baryta came from one direction whilst the lead came from another; the combination of the two producing the desired effect.

Water with carbonic acid and potash in solution coming in contact with sulphate of baryta, will effect a partial decomposition at a moderate temperature; and should another element, such as lime, abstract the acid, sulphate of baryta will be reproduced. The changes taking place, and the evolution of sulphuretted hydrogen, and the consequent variable degrees of intensity, must cause various products and change the sulphurets into carbonates, oxides, &c., from below towards the surface, as already explained.

After the fissures have been produced and the crystalline aggregation of minerals having forced open the joints to the magnitude of lodes, another variety of solutions may percolate through the pores, or cross-heads, and contaminate the contents of the veins already formed with quartz or other substances, or dissolve the minerals and carry the same away to other vacuities, or the pores or cleavages of another rock. Sometimes the solutions permeating the series are so free of silica that the spaces between the mineral masses in the veins are left hollow; presenting beautiful cavities,—decorated by brilliant crystals, and radiating from the surface on which they are formed. Gold, silver and metallic copper are frequently formed in such cavities, growing out in elegant moss-like, or arborescent forms, the whole exhibiting a rich display of the flowers, as it were, of the mineral kingdom.

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* Herland, Dolcoath, Crenis and other copper mines have produced silver under such circumstances.

Thus we are able to comprehend the varied conditions of mineral veins, and the development of minerals in certain rocks by chemical affinities, governed by the terrestrial electro-magnetic forces.

With reference to the effect of a slow electro-magnetic action on matter in a liquid state, it has been so much pointed out, that it is scarcely necessary to repeat it. However, as the object is to lay before the reader as many facts as possible under different aspects or conditions, repetition may be convenient so as to refresh the memory in the progress of our inquiry.

Various compounds are produced by a battery (be it galvanic or a simple magnet) which are not formed by the ordinary kind of experimental investigations. Disunited elements in the electro-magnetic action of nature are presented to each other in a nascent state, which is highly favourable to the formation of new combinations. For a long time it could not be conceived that such apparently feeble electro-magnetic forces as those we find in the laboratory of nature, could overcome strong affinities and decompose hard bodies, and produce new combinations. It was commonly supposed that a very energetic action was necessary to produce some of our mineral productions. In experimenting with batteries, M. Becquerel found substances considered insoluble, easily dissolved, and capable of being recrystallized; the electrical action being slow, the chemical action was slow also, so that the component molecules had time to arrange themselves according to the laws governing crystallization, which cannot be effected by chemical forces of greater intensity. All the chemical actions which have produced artificial minerals, similar to those found in veins, can only be produced by *feeble currents continued for a long period*; if we operate with apparatus of strong intensity, all the elements are isolated, and no combination is possible. To obtain an insoluble crystallized substance by electro-chemical reactions, it is sufficient to make it combine with another which is soluble, and afterwards operate by means of very slow decomposition.

Mr. Fox, in his researches, found by an examination of water taken from different mines in Cornwall, and from various parts of the same mine, that different varieties of saline solutions now exist in neighbouring strata. "The contact of large surfaces of rock," adds Mr. Fox, "with water, differing in its saline contents from them, must generate electrical excitement; and it should not be forgotten that the circulation of water would be liable to frequent changes, in consequence of obstruction in the fissure or their occasional enlargement, so that the contents, as well as the temperature of the water, would be subject to many modifications." Hence we have abundant facts to show, not alone in foreign countries, but in our own island, the existence of subterranean electro-chemical forces in rocks, which give rise to numerous compounds and reactions amongst the elementary substances.

We may therefore easily conceive that the produce of veins of fractures running transversely to the grain are more or less dependent on the composition of the rocks in which they are enclosed. But if the veins be splits more or less parallel to the meridional cross-courses, and consequently in the direction of the primary grain and cleavage, their mineral contents will be dependent on the S.W. and S.E. oblique joints, acting as feeders like roots, principally the former, and therefore these veins are not subject to vary, like east and west, according to the character of the bounding walls. Hence a lode may carry lead beyond the productive rocks in the direction of the lode north into barren ground, and sometimes ooze out into the sandstone beds which sometimes cover such rocks. Miners, not knowing these laws of mineral productions, have never studied these important distinctions; they reason on all lodes alike, be they N. and S. or E. and W.; and their notions of strata are exceedingly vague: therefore we need not wonder at the losses incurred in mining speculations.

However, notwithstanding the want of general principles, the intelligent miners know from experience that the quality of the lodes is dependent on the character of the rocks in which they are enclosed, and also that cross-courses are essential for the enrichment of a mineral district. It matters not how favourable the composition of the rocks may be, if not cut up by meridional splits (cross-courses) so as to be irrigated from the sea with saline solutions, and cause strong tension to produce fractures and chemical activity, they cannot be rendered productive of large masses of ore. Again, lodes situated on the E. or W. flanks of granite, are more subject to change in their direction, as regards contents, than those running parallel to the north flank. The former may pass from clay-slate to schorl rock, and thence to granite, causing a variation from a rich copper lode to that of tin; whilst the latter may continue more or less the same throughout, or at all events not subject to a permanent change. An east and west lode running direct into the middle of a great mass of granite will not only become a tin lode in schorlaceous granite, but will dwindle into minute fissures as it approaches the harder nucleus; whereas a lode running parallel to the flank, may continue for miles within the external productive exfoliated portion of the granite, between the harder nucleus and the lapping junction of the clay-slate. These various conditions change the character of the lodes often from copper to tin; again, from tin to iron, zinc, lead, &c. Examples of these changes may be seen in the mineral districts of St. Austell and Fowey, and also near Chasewater in Cornwall. (See the Plates, illustrating the principal mineral districts of Cornwall and Devon.) Indeed they are so common and so well known amongst miners in all the mineral districts of the world as not to require further comment. In South America the changes are often observed in the quality of the great lodes of fractures—from auriferous to argentiferous, thence cupriferous, zinciferous and ferruginous.

The Wenzal vein at Furstenburg runs nearly vertically from N. to S., obliquely to the more or less parallel bands of gneiss, which are about 60 feet thick, dipping east. See Plate XV.

Each of these bands form a distinct variety of rock. The first is very micaceous; the second passes into argillaceous slate; the third is hornblendic,—and scarcely any mica can be detected in the fourth. This vein is shifted in depth to the westward by several oblique flookans, or clay joints or splits, and it was between two of these impermeable veins, distant from each other about 240 feet, that it contained those riches for which it has become so celebrated.

In the first band of gneiss, the vein merely formed an imperceptible string of clay; in the second it suddenly acquired a thickness of from 12 to 18 inches, and was composed of sulphate of baryta, antimonial silver, red silver, and argentiferous grey copper. The antimonial silver was always found in large masses. In the third band the thickness of the vein is preserved by the sulphate of baryta, but the silver ores disappear, and a little sulphuret of lead is the only ore found. In the fourth band of rock the silver ores become as abundant as in the second, but they gradually disappear in depth, and are replaced by selenite (sulphate of lime), a little sulphuret of lead, and the vein dwindles into a mere thin fissure in the bottom.

These changes, with similar local accumulation, were also found in the celebrated silver mines of Guadacanal in Spain. The angular position of the oblique flookans and the lode were the same as the one above; but the geological formation of the latter district is composed of a variety of chloritic and micaceous rocks.

The silver mines of Norway, Germany, Spain, Chili, Peru, New Granada, &c., are all, more or less, in the meridional bands, enclosed in the gneiss and the micaceous and chloritic schists; and these laminated rocks frequently contain flakes of native silver enclosed in the cleavage: and consequently the rock, apart from any lode, often contains upwards of 2½ oz. of silver per ton. Indeed I have seen rocks in equatorial America, not only enclosing silver, gold, &c. in the cleavage, but also producing silver, and even quicksilver, in rocks of a granular character, without indicating the least visible traces of such metals by careful inspection.

CHAPTER XVI.

CONTINUATION OF THE CHARACTER OF METALLIFEROUS ROCKS AND THE PRODUCTION OF VARIETY OF MINERALS IN THE FRACTURES.

The ores generally mixed with each other are those that have the same mineralizer, and the same degree of solubility, and others which are soluble in different degrees, but in point of local situation are nearest each other. Sulphuretted copper ores, yellow and grey, are often mixed with iron and arsenical pyrites and blende. These ores chiefly accumulate in granular rocks in east and west fractures, but are also found in isolated masses in slaty and decomposed argillaceous rocks, as already explained in the previous chapters. The black copper ore, and the green carbonate (malachite), are frequently found in granite with the oxide of tin. Sulphuretted silver ores vary from bright red to dark grey, and are generally accompanied by sulphurets of lead and zinc, and also iron pyrites. Antimony and cobalt ores are also often associated with silver and lead ores, and predominate in north and south lodes; and especially in gneiss and micaceous schists. Iron pyrites is almost an universal companion of minerals, and often causes by its chemical activity the accumulation of other minerals; hence it is a favourable indication in mining districts.

Sulphuret of lead is frequently accompanied by blende, pyrites and white or sparry iron ore, and also argentiferous pyrites, calamine and cobalt, when formed in the primary clay-slate. The sulphuret of lead formed in the sedimentary limestone contains but a small proportion of silver,—the matrix of such lodes being principally carbonate of lime, fluor and heavy spar.

Sulphuretted ores can only be formed *within* the rock; if exposed to pure water or to the atmosphere, the metals would be oxidated or precipitated: hence *sulphurets* are seldom found formed in old workings. As the quantity of sulphuretted metals that can be conveyed in a state of solution is very small, it must necessarily take a long time to crystallize and fill a vein,—and more especially in large crystals.

The substance most abounding in lodes within the primary and the older sedimentary series is quartz, in a more or less crystalline state; the colour and texture of which depend on the metalliferous quality of the bounding rock. Quartz veins of a blue and dark aspect, with cavities lined with small crystals of the same substance, is a sign of poverty in minerals; whereas the red and other friable varieties indicate the presence of iron, and consequently other minerals, if in the neighbourhood of metalliferous rocks.

Fragments of the bounding rock are commonly found enclosed in the quartzose matrix, cemented together with the siliceous solutions. These fragments show most distinctly that they were separated from time to time from the walls of the lodes during the gradual opening, as shown in Plate XIII.

This effect alone shows the inconsistency of supposing that the lodes were at any period *open fractures* and subsequently filled by mineral matter; such conditions could never have existed. The isolated cavities which are occasionally found in the compact argillaceous rocks and limestone formation, have been open spaces, and subsequently filled by sulphurets, which have permeated through the rocks; but the fractures have been gradually opened as the crystalline matter increases, like water freezing in a joint, and capable of forcing it open whatever may be the amount of resistance.

In the mining districts of Cornwall and Devon, where the rocks are much intersected by cross-courses, the fissures, or east and west lodes, contain masses of rocks and mineral characteristic of the rocks they traverse. When they intersect the pale blue or light grey granular and massive clay-slate, or the grey and moist porphyritic granite, they contain copper; in passing into dark schorlaceous rock, the copper disappears and the lode is changed into tin. Should these rocks dip either to the east or to the west, the average of the masses of ores formed within such fracture will incline accordingly, as well as the irrigating cross-courses. Meridional joints filled with clay, or any impermeable substance, may have a contrary dip, and thus dam the mineral solutions and confine the accumulation to a more limited space than the dip of the bands of rock, and consequently cut off apparently the continuation of the dip of such bunches in the direction of the productive ground.

When a band of rock is found very dry and of a close crystalline grain, it is unfavourable to produce mineral. A mere change in the colour of the rock indicates a change in the contents of the veins. When we examine the changes in the contents of the fractures intersecting the sedimentary series, the influence of the bounding beds is much more striking than in the primary rocks; the subdivision of the beds being so distinct as to afford an excellent and most unequivocal section for studying the phænomena.

The sedimentary rocks of Aldstone Moor, Teesdale, Swaledale, &c., consist of beds of shales, grits and limestones, intersected by fractures; the minerals in which are chiefly found opposite the limestone beds, being the principal metalliferous rocks. See Plate XII.

The matrix of the veins also frequently change as they pass from the gritstone to the limestone; in the former it is often sulphate of barytes and spar, whilst in the latter it predominates in carbonate of lime and carbonate of barytes.

Again, the continuity of the sedimentary seams are destroyed by a dislocation, so as to bring a stratum of limestone opposite a stratum of sandstone; the veins are never so productive in lead ore as when both sides are limestones. The contiguity of the metalliferous beds on both sides of the fractures appears essential to keep up the crystallizing action from the ruptured face of the limestone.

When the strata are but slightly shifted, it is interesting to observe the tendency of the elements of each stratum to reunite obliquely with those of the opposite.

Again, we find horizontal dislocation destroying the continuity of the fissures in depth, and also divided by thin seams of clay and thick seams of hornblendic rocks, which have been forced between the beds subsequent to their deposition; and these frequently separate the contents of the veins of the respective rocks: and thus even a section of the contents of the fractures exhibits the order of the sedimentary demarcations of the bounding rocks, as described in Plate XII.

This simple fact alone is sufficient to invalidate the idea that the veins of fractures have been filled either from above or below, and clearly demonstrate that such veins have been gradually forced open by lateral crystallization from the bounding walls.

In Derbyshire the metalliferous limestone is interstratified by seams of hornblende, called toadstone. The latter rock is considered by the Plutonists, to be lava injected in a molten state into the joints of the beds. These seams are composed of hornblende, felspar and oxide of iron, and, although generally hard, are frequently found in many parts as soft as clay; and this substance is gradually and imperceptibly permeating and swelling between the seams of limestone, like siliceous veins in a moist state, but much more active than the latter, and consequently tend to disturb and dislocate the uniformity of the series. When a vein of lead is worked through the first limestone down to the hornblende seam (toadstone), the ore is, as it were, cut off; but on sinking through this seam to another bed of limestone the lead-ore is found again, until it is cut off by a lower bed of toadstone, under which it appears again in the third limestone.

Generally speaking, the upper part of the mountain limestone series is the most productive in the north of England, and within that portion there are certain beds much more productive in lead ores than others. The ore is not only found in the fissures of the above limestone, but also in immense isolated masses in the middle of certain beds. Large quantities of lead ore and calamine are found in such positions on the Continent, as well as in England, and the hæmatite iron ore of Ulverstone is similarly formed. The metalliferous solvents necessarily accumulate in joints, fractures, horizontal or vertical, and in all cavities, especially in the producing rock; we may therefore well conceive the various characters of such mineral aggregation.

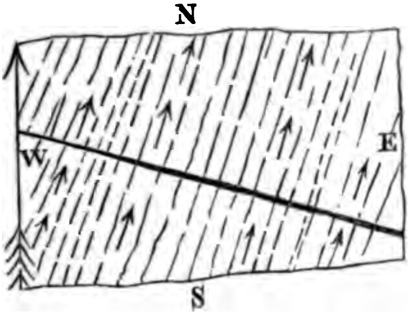
Sometimes the lead ore will ooze out of the limestone into the millstone grit, and there crystallize in masses in the direction of certain joints of the structure below; as at Mold in Flintshire. Similar masses, called tumblers, are also formed in the same manner on the back of metalliferous clay-slates in Wales and Devon. Indeed the metalliferous productions of rocks are so various, and governed so much by local physical conditions, as to render it too laborious to enter into details.

Having already dwelt so much on the character of rocks in the preceding chapters, we shall confine ourselves here to the favourable and unfavourable conditions of the angular position of the cleavage planes, fractures and meridional joints, in order to show, that however favourable the contents of the rocks may be, the granites, porphyries, clay-slates, or any other, yet, if they be not intersected by suitable irrigating cross-courses, or some other conducting medium of saturation, and fractured at certain angles to favour the formation of their containing minerals, their mineral qualities are of no avail and will deceive the uninitiated.

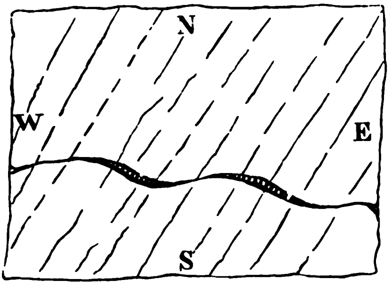
CHAPTER XVII.

ON THE INFLUENCE THE ANGULAR POSITION OF THE FISSURES, THE BEARING OF THE GRAIN AND PORES OF THE ROCKS, AND THE OBLIQUE CROSS-COURSES, HAVE ON THE ACCUMULATION OF MINERALS.

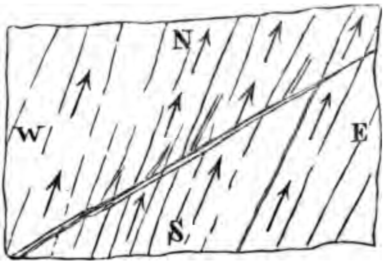
THE circumscribed nature of the mineral portions of a district, and even in the lodes themselves, together with that of the masses of minerals conforming to the dip of the structure of the bounding rocks, are facts well known to old miners. Not only are the bunches of ore frequently confined to the oblique intersection of an elvan by the lode, but we find also the lodes vary in productiveness according to the angle of the bends. These important observed facts, together with the well-known influence of cross-courses, flookans, slides, &c. on the local accumulation of minerals, may be seen in all mining districts; thus showing how essential it is to study the laws by which they are governed to ensure success in mining operations. We are prepared to find from the evidences brought forward in the preceding chapters on the polarity of crystalline aggregations, the order of the structure, the tensions, ruptures, and constant aqueous chemical activity, that these mineral productions are not the effects of blind chance forced up in all kind of rocks, or of violent igneous catastrophes by internal incandescent matter, but according to laws and order as beautiful as that observed in chemical operations, and in the economy of the vegetable kingdom. However, any attempt at generalization or prediction founded on local effects, without the necessary acquirements obtained from long and extensive practice, underground as well as on the surface, in all the various complicated cases, would lead to incorrect analogies and conclusions from wrong assumptions. For the want of sufficient experience in different mining districts, many persons have taken the exceptions for the rules, and thus led to error. It has been shown that the cleavage planes of the schistose rocks, the pores of the compact clay-slate, and the porosity of the granite have a general bearing a few degrees east of true north, and we find that the fractures approaching a right angle to this bearing are the most productive in minerals. See diagram.



Again, even in the same metalliferous rock, without the least change in its character, composition, or structure, should the fracture have an undulating bearing, as shown in the following sketch, the masses of ore will accumulate more or less in the N.W. angles, the lode being left almost barren in the N.E. angles.



These facts are so general that they have been observed in Cornwall, Devon, Wales, Germany, and America. The following will illustrate the unfavourable angle of the rupture to form a mineral lode, which necessarily follows from the facts above explained*.



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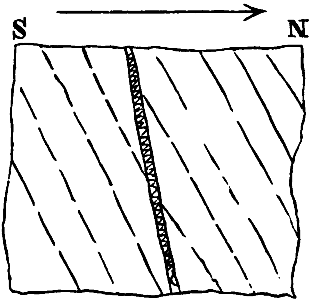
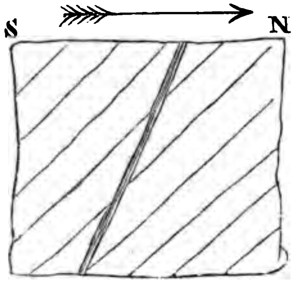
* Tin ore is however frequently formed in this angle, even in copper lodes, when in granite and the clay-slate on the flanks.

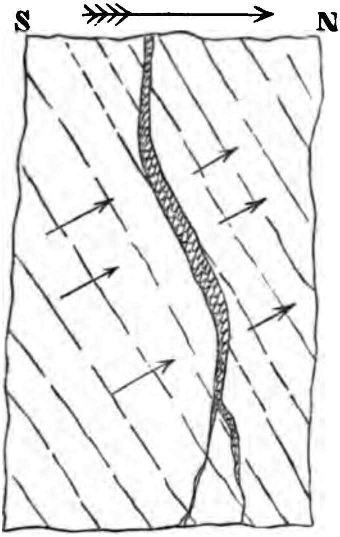
The following observations are taken from notes made underground in South America, Cornwall, Devon, Wales, Ireland, and Germany.

East and West Lodes underlaying North.—In granite, porphyry, and compact clay-slate, a good hard foot wall is a favourable indication, as far as the fracture is concerned; and in exploring this wall, however small and poor the joint or lode may appear, it is the safest to follow, and will lead ultimately to the greatest deposit should the rock be of a metalliferous character. A broken foot wall and a hard smooth head wall are unfavourable indications to produce large masses of ore. It is generally observed that when the jointy structure and the underlay of the lode occupies the angles delineated in the following cut, they are the best and most productive lodes. When these angles vary, the lodes vary also in quality. Lodes underlaying south in the same structure are productive on the back, and seldom continue to great depth. When the planes of the structure dip south, the lode also underlaying south, as shown in the diagram, the conditions are extremely unfavourable; therefore such lodes must have other very favourable conditions,

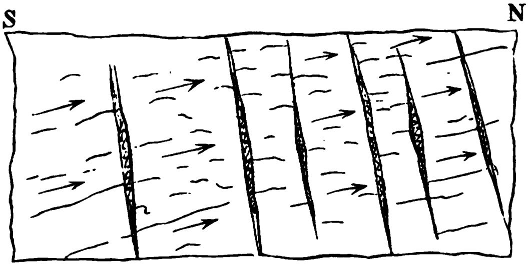




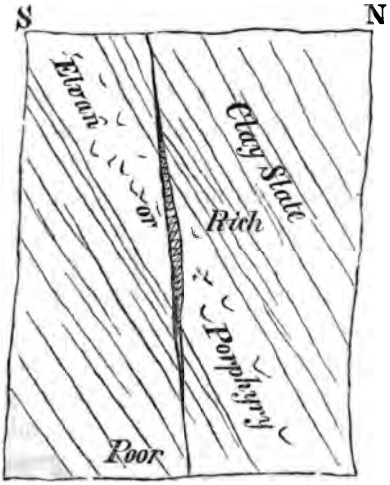
such as cross-courses, &c., to render them of value. These divisional planes of the crystalline rocks act in the same manner as the negative plate in the decomposing trough of a battery, on which the crystallization takes place at right angles to the plane; and the nearer a fracture becomes parallel to this angle, the more favourable it will be for the formation of crystalline matter, and the opening of the joints by the accumulated crystallizing forces. The following is a section of a lode in a porphyritic rock in South America.



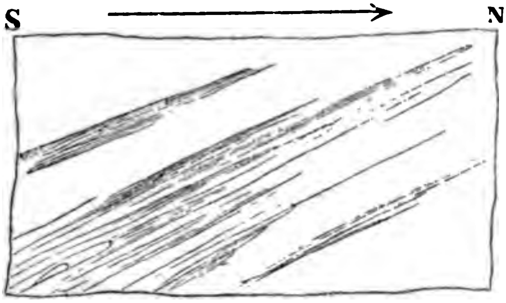
The lode was very productive in the metalliferous part of the rock, where it was parallel to the structure, but became poor and dwindled into joints when varying from this angular dip. See section of the Marmato lodes. Lodes underlaying very flat southward, and to the north at similar angles, are unfavourable: the former is very showy on the surface, frequently producing small rich shallow bunches and good-looking gossans, thus leading many to imagine that they must be equally productive in depth as all other lodes presenting similar superficial indications. Generally speaking, lodes underlaying north from 10° to 20° from the perpendicular are the most favourable for continuous rich lodes to great depths. The parallel lodes of this underlay, in granite, porphyry, and compact clay-slate, are productive in parallel bunches, as described below.



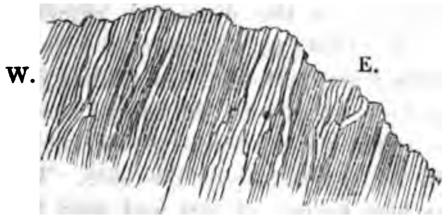
This parallelism of the bunches of ore is also observed in the line of bearing; the bunches getting gradually shallower as we proceed north. This angular rise of the molecular action northward varies in South America from 10° to 30°. In Cornwall the bunches of ore in the southern lodes are considerably deeper than they are to the north. Porphyritic veins in clay-slate are very productive of minerals, should the parent base be metalliferous. In a great number of the east and west copper lodes of Cornwall, as well as in many other districts, we find that an oblique intersection of an elvan has a very important influence on the production of ore. So much is this the case, that the ore has frequently been confined to the ruptured part of the elvan, like that of the lead ore in the limestone beds of Derbyshire, the other part of the lode being unproductive, with the exception of the filtration from the main bunch. See section.



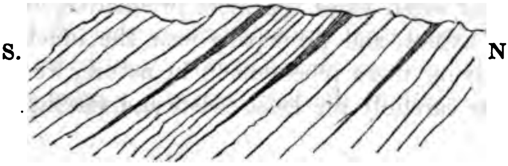
Slaty districts or schistose rocks are not favourable for the formation of east and west lodes. The mineral produce of such rocks is generally found running more or less in the same bearing. In the gneiss and micaceous schist we frequently find silver and lead lodes formed conformably to the bearing of the cleavage planes, and therefore more or less north and south. The shoots of ore in these lodes rise from the south at angles varying from 10° to 30°, as described in the sketch.



In the clay-slate part of the series, and more especially in the transition of the primary clay-slate into the sedimentary, the copper becomes formed like wedges and isolated slabs in quartz, within the limits of certain metalliferous bands, in the absence of lodes. These kind of formations are very common in the slaty rocks of North Wales.



Sometimes we find the mineral forced into the planes of the sedimentary beds, appearing to the uninitiated as lodes interstratified, or sometimes called contemporaneous veins, as shown by the annexed sketch.



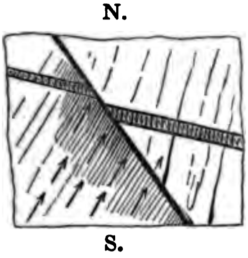
These descriptions of mineral aggregation in the planes of the sedimentary beds, and also in the planes of cleavage, are the most deceptive kind of veins; frequently producing fine-looking gossan and rich ore near the surface, but dwindling into a mere joint in a few fathoms in depth, especially those inclining south.

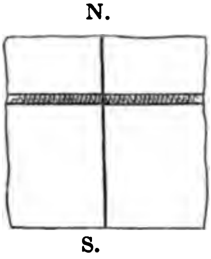
The north and south lodes which are enclosed in the planes of the schistose rocks are not dependent on the immediate bounding rocks for a supply of ore. They are fed by branches coming in from the S.E. and S.W., but principally the latter; therefore fine bunches of ore may be found in such lodes enclosed in very uncongenial ground. When these lodes intersect the slaty bands obliquely, they then become influenced by the character of such rocks in the same manner as the east and west lodes; with this difference, that the mineral becomes formed in oblique shoots in the direction of the veins instead of crystallizing transversely.

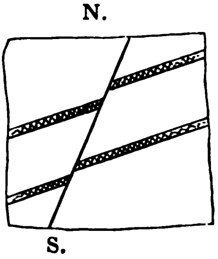
Roots and Branches of Mineral Veins.—The meeting of a number of veins either in depth or in a horizontal direction, is favourable for the accumulation of minerals, should they occur in a metalliferous rock under favourable conditions. But when such veins and branches unite in a hard unproductive ground they are of no avail, and more especially in the veins of fracture, or east and west veins. In east and west lodes the real feeding-*droppers* are the divisional planes underlaying north into the lode; those in the opposite side are, generally speaking, branches *from* the lode. The feeding-joints or roots, as it were, of the lode, are also on the south; those joints filled with ore on the north are the branches by which the mineral gets forced into the country from the lode. The south-east veins appear the best feeders of east and west lodes, and are sometimes the most productive portions of the lodes. In north and south veins the feeders are from S.E. and S.W., and the dispersing branches of these split veins are the N.W. and N.E. In the majority of instances we find the south-west branches in the north and south lodes the most productive, but only to a very limited extent, and principally near the junction. However, in studying these phænomena in nature, we must in all cases examine carefully the local twists and various contortions produced by the constant molecular action of the elementary bodies.

Cross-courses.—The angular bearing and inclination of the cross-courses and flookans have a most important influence in the enrichment of lodes. Those running N.W. cause greater dislocations and accumulations of minerals than the cross-courses bearing to the N.E. To enumerate the mines in which these effects are observed, would be to note all the mines of celebrity in the world; therefore I must beg reference to the Plates for ocular demonstration.

The following diagrams represent, first, the most favourable conditions of the cross-course and lode,—the second moderate, and the third most unfavourable.







The north-west cross-courses frequently become sufficiently productive in mineral to work on, in the absence of the east and west lodes, and are called in Cornwall "Caunters."

The degree of richness will depend on the character of the rocks to the S.W. of the lodes, and the nature of the ground through which the cross-courses run from the south. Hence it becomes necessary to reflect well on all the influential circumstances, as various combinations of elements will give rise to many new and complicated results.

We frequently find the lodes enriched only on one side of the intersection, the opposite being comparatively poor. This is often produced by impermeable flookans; the mineral solutions being dammed on one side, the opposite part of the fracture being filled only with the substances which may exist on the other side of the intersecting flookan. Very large masses of ore have been formed by the horizontal oblique intersection of flookans with the lodes. The large mass of lead ore at Esgyr Mwyn in Cardiganshire, and the immense deposit of copper ore in Anglesea, were produced by such intersections in conjunction with the local twist of the cleavage of the rocks.

Porphyritic or Elvan Courses, or Tabular Masses of Crystalline Rocks enclosed in Clay-slate.—When a fissure intersects clay-slate containing bands of granite, porphyry, or any other rock differing in character with the series, its contents become influenced by them; according to their composition and angular position, as illustrated in the diagram, page 102.

An elvan course inclining north and intersected obliquely by a lode underlaying north, will be the means of enriching the fissure at the intersection according to its conducting metalliferous quality, below which the lode seldom continues productive.

Many miners call any description of granular rocks differing from their killas Elvan, and thus often lead to erroneous conclusions. The productive "elvans" are porphyritic or granitic veins, which, when intersecting a series of clay-slate, become equal to the junction of granite for supplying the metalliferous elements; hence real "elvans" are favourable indications when found in good angular positions.

One of the most noted examples of the influence of an elvan course may be seen at Great Wheal Alfred. This rock runs from S.W. to N.E., underlaying north; the lode intersects it obliquely; while in the slate, on the eastern side, it contained mineral in moderate quantity; but in approaching the elvan it became much richer, and yielded sufficient ore to afford a profit of £140,000. After quitting the elvan on the western side, the lode became poor, and eventually the mine was abandoned as unproductive.

It is also frequently observed that all the lodes intersecting such elvans are more or less productive at the intersection, and become poor beyond them, showing most clearly their influence in the filling of the ruptures with minerals. In the event of such lodes meeting and intersecting similar elvans in their linear direction, or with productive cross-courses, they again become available by means of distinct conductors, which has been the case at E. and W. Alfreds.

Ironstone courses.—These ferruginous hornblendic rocks are not productive *per se*, but their angular position and compactness frequently cause the enrichment of lodes by damming up the contents of a series. A wide "ironstone" course, like that seen at "North Pool," and also South Roskere, inclining north, renders the lode productive in the upper part of the intersection, but completely cuts off all supply from the under part of the lode. Should such an "ironstone" mass happen to incline north and bear E. and W., it is extremely unfavourable to the production of ore in lodes intersecting it. If the ferruginous rock form a band enclosed in the cleavage of the series and run N.E., masses of ore will be found in the lodes intersecting it, like those of Holmbush, on the upper side only, the amount of which will depend on the rocks and cross-course situated on the western side; below which large masses of ore are seldom formed.

Oblique trunks of Minerals.—Oblong masses of minerals are frequently found aggregated in the midst of granites and limestone rocks, and often in slaty districts.

The "*Carbonas*" of St. Ives Consols are formed by means of numerous small veins like roots from the south, converging into one grand trunk of about 10 feet diameter, growing or extending towards the N.E., at an angle of about 8° from the horizon, surrounded by the granite*. Indeed it would be an endless task to describe all the variety; therefore I must beg reference to the accompanying Plates and the facts *in situ* for further information on this interesting and truly important subject.

CHAPTER XVIII.

RECAPITULATION.

In the preceding chapters I have endeavoured to reduce all our observations into a system conformably to the well-known laws of terrestrial physics, and thus concentrate the scattered rays of useful knowledge which have been obtained from time immemorial, so as to render them useful to our industry, and especially to mining; the diffusion of the many important discoveries amongst a mass of untenable hypotheses, having hitherto rendered them uninviting and of no avail to the progress of real geological science.

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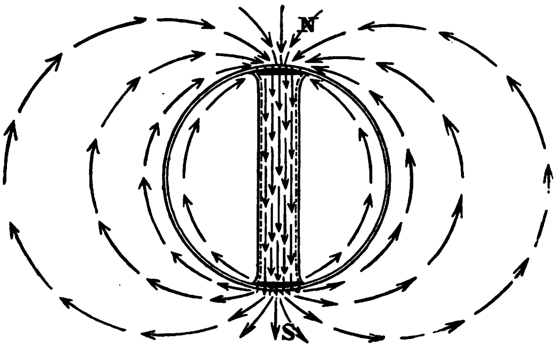
* The above is a tin mine. Tin ore is frequently found sufficiently productive in veins running in the direction of the grain, *i. e.* N.E.

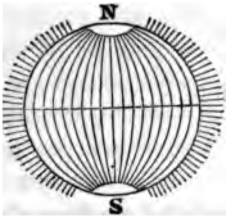
First.—It has been shown that the power we call magnetism is universal, and that our globe is a great magnet, with the poles of divergence and convergence placed in its axis, as described in the diagram. The enveloping force rises out of the antarctic region and passes through the earth, sea and the atmosphere towards the equator, and thence to the arctic region to complete the known circuit of power. Hence the curves of magnetic force not only imply the directions of the force which are made manifest when a little magnet is placed amongst them, but the lines of power which connect the poles and the permanent bonds of the elements of the terrestrial sphere. The more closely we examine the laws of magnetism, and particularly as they are presented to us in their terrestrial operations, the more surprising will their general influence appear to be. We learn by careful research that gravitation and electricity are the effects of the same great cause, which is ever busy in producing the necessary conditions of change in the earth to suit the wants of animated nature. Every substance is under its immediate and constant influence; the rocks, seas and all the minerals found therein are kept and moulded into exfoliated concentric spheres and arranged according to their respective densities by the terrestrial magnetic

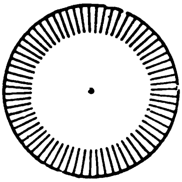


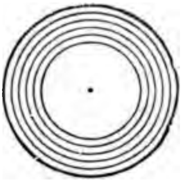
power, and the vegetable and animal life controled by its radiant force, called by Dr. Faraday diamagnetic. All gases and vapours necessarily ascend by the repelling force of the tension of the denser bodies forming the nucleus.

The system of spherical magnetic forces, arranged according to their densities and the substances with which they are combined, necessarily causes a great tension from pole to pole, the disturbance of which in one part is accompanied instantly by a disturbance of the tension in another part. The tension of water is greater than air, hence a bubble of the latter will ascend in the former. The uniformity and direction of the natural magnetic stream may be altered locally by the presence of a substance capable of transmitting a concentrated stream of the force like a magnet, and thus rob a large amount of the feeble currents in its vicinity; and should the disturbing agent not be capable of movement so as to conform to the natural direction of the force, a local bend will be produced.

Secondly.—We find that the structure of the crystalline rocks is not alone governed by the power of cohesion or aggregative attraction, but likewise by the great polar force, thus producing beautiful geometrical divisional lines in the primary base, as exhibited by the following circles:—



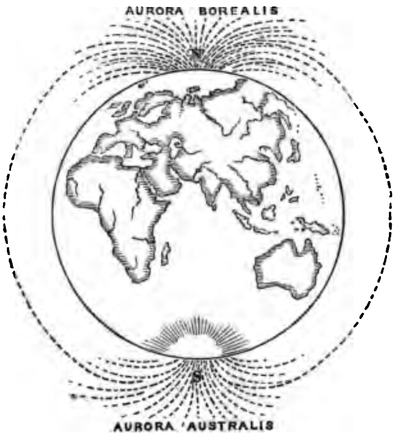




The first circle represents the polar lines of cleavage, with the external radiant repelling actions (diamagnetic); the second circle, a section showing the radiant planes of cleavage consequently formed by a compound of polar and radiant forces.

The third section indicates the concentric arrangement of fluids, or the terrestrial spherical exfoliations. These kind of divisions are frequently impressed on semi-aqueous crystalline matter. Hence the cleavage planes of the primary rocks are not mere local phænomena, but an universal structure, a polar and radiant grain, formed from pole to pole, produced by the permeating action of the magnetic force, through which the subterranean substances are conducted, and the liberated gases escape.

Thirdly.—The primary film forming the base is a compound of crystals formed from aqueous solutions, and they retain a portion of the mother liquid. These are constantly subject to decomposition and recomposition, and the formation of many compounds in their circuit of activity, by the constant influence of the ever-acting polar force, and the surrounding sea of saline elements. The unequal degrees of aggregation cause variation in the surface; hence some parts protrude above the surface of the ocean and form dry land, whilst other parts are depressed, as seen in the following figure:—



The above sketch will also show the pointed configuration of the island and continents towards the south, arising from the action of the oceanic currents which are propagated from the south to the north by the great polar force.

Fourthly.—It is made evident that the polar splits and transverse fractures which are observed in the crystalline rocks, and their superincumbent sedimentary series, are produced by the polar tension; and that all description of crystalline veins have been formed by the progressive opening and filling of the ruptures by the internal solvents in the intersecting rocks, according to their respective composition. These mechanical and chemical actions being the effects of the subterranean polar currents, not only fill every fissure and vacuity with solvents, by which crystals are formed, and swell open the joints by their growth, but they cause also new fractures and dislocations, according to the local physical conditions. This gradual opening during the growth of the crystals from the sides, accounts for the isolated masses of the bounding rocks found in them, and frequently in angular masses separated horizontally from the bounding walls. The east and west being veins of fractures are supplied with elements transversely, whereas the meridional splits are filled longitudinally in the direction of the force.

Fifthly.—The order of the "heaves" or dislocations has been explained, and also the conditions favouring the accumulation of minerals, and the rocks which are found most congenial to the production of different descriptions of minerals in all parts of the world. I have brought forward abundant examples to prove that every mining district has its conducting metalliferous channels, cross-courses, or feeding pores. It is of great importance to bear these facts in mind, to avoid being misled with the notions of supposing that a lode found to contain a rich mass or masses of ore in one place should be equally rich miles off in the direction of the rupture, although in barren rocks; which ideas are too often encouraged.

Sixthly.—I have endeavoured to connect those vague indications applied by old miners in their operations and reduce them to a general principle for the guidance of the intelligent miners. I trust the increased practical experience in their daily avocations and habits of observing, with the aid of the principles herein propounded, will enable them to form a more correct judgment of ground, and considerably reduce the present amount of useless and expensive explorations, and lead them with more certainty to new discoveries.

The more careful these investigations are made, the more convincing and satisfactory are the results; therefore these great principles of polarity, in combination with the various composition of the rocks and their structure, may be safely applied to any mining district in all parts of the world. These laws of geology and magnetism are therefore of vast importance to the practical miner and engineer; and the elucidation of the subject to the furthest practical extent, and suitable to the capacity of ordinary miners, is the greatest desideratum which now remains in the art of mining, since the operations carried on for the discovery of the masses of ore contained in mineral veins and metalliferous rocks, cavities, &c., not only constitute one of the heaviest expenses of mining, but it is the vague and precarious result of these trials which chiefly stamps the proverbial character of hazard and uncertainty which is attached to the pursuit. I therefore trust that the foregoing chapters, with the aid of the numerous accompanying Plates, illustrating the principal mineral districts, will tend to simplify the science and enlighten those who are interested in the subject, and remove in part that embarrassment and complexity which have hitherto impeded the progress of this department of geological science.

CHAPTER XIX.

ON THE POLARITY OF EARTHQUAKES, AND THE NATURE OF THE CONTENTS OF THE MAJORITY OF VOLCANOES.

Those who have had no experience in these phænomena are labouring under the impression that earthquakes are the effects of an incandescent nucleus, *i. e.* the violent action of molten matter in its attempt to burst and break through the thin shell by which they confine it within, and on which it is supposed the Creator has placed the organic kingdom after it became cool. We have already pointed out the inconsistency of such a state of things; and it is difficult to conceive how any rational being could for one moment encourage such notions, as to imagine that a globe of water, in combination with other substances with which it is combined, could have retained within it a permanent globe of molten matter. The idea is truly monstrous. It would never have been thought of, but for a few, and comparatively speaking, insignificant holes, which occasionally become inflamed by strong chemical activity, and thereby melt a portion of the rocks during the period of the inflammation. With equal reason the clouds may be considered molten matter, because we see lightning and fiery meteors amongst them occasionally. These pimples of eruption would be scarcely perceptible on a globe of 3 feet diameter, and probably, with few exceptions, would not penetrate to the depth of the varnish coating; besides nine-tenths of those observed are aqueous, and not igneous eruptions. Having studied them from the magnitude of the Andes to the diminutive dimensions of mole hills, like those of Turbaco near Carthagena, I have found them all, without exception, similar in character, viz. the effect of local chemical action; the great ones being situated along the lines of the meridional splits, and the secondary eruptive pores on the transverse fractures. The sudden ruptures, as well as the occasional rapid expansion of the gases generated, produce a vibratory jar, which being propagated along the cleavage planes or through the pores of the rocks, give rise to superficial oscillations, and thus cause earthquakes and subterranean thunder for thousands of miles from south to north. The shock of the earthquake in Chili, 1822, was felt simultaneously throughout a space of 1200 miles, from south to north; the lateral oscillations being confined to narrow bands. The following are a few registered by the author in South America:—

1834. Jan. 20.—Violent shock from Chili to St. Martha in a more or less meridional direction; caused great damage in the line of its maximum force. Its meridional disturbances were felt over a space of 1500 miles of linear measurement; but the transverse oscillations scarcely extended over 200 miles of land.

1835. Feb. 20.—Ditto, a great number, and continued more or less daily until the month of March.

1836. Jan. 4.—Slight shock from the south.

Jan. 8.—Ditto.

On the central Cordillera, from four to five shocks almost daily, from the 1st to the 15th.

1837. Nov. 10.—A shock from the S.S.W., accompanied by subterranean thunder, after heavy rains.

Nov. 27.—Ditto, after a few days' intense heat.

1838. June 19.—Two violent shocks; no oscillations; the ground appeared to heave up.

Aug. 9.—Sounds heard in the mines, passing in the direction of the cleavage from south to north; no oscillations; the magnetic needle much affected.

1838. Aug. 11.—Shock accompanied by a very loud explosion, apparently from the volcanic vent of the Paramo de Ruez.

1839. May 28.—A severe shock, continued for nearly a minute.

Sept. 21.—Ditto.

Sept. 22.—Ditto.

Sept. 28.—Ditto.

All in the usual direction, from south to north.

Oct. 15.—A great number of shocks during the last few days. The quantity of rain fallen last month exceeds that of any month in the last three years, viz. 15½ inches. Natives consider earthquakes to follow the extremes of wet or hot weather.

Nov. 28.—Ditto.

Dec. 13.—Three very violent shocks from the S.S.W. to N.N.E.

1840. Jan. 2.—Strong shocks from the south.

June 12.—Ditto, the oscillations confined to very narrow limits.

Aug. 22.—A sharp shock from the south.

Dec. 11.—A severe shock from the south, lasted fifty seconds; several houses thrown down in Antioquia in its line of bearing.

1841. Mar. 12.—Slight shocks from the usual direction.

Mar. 19.—Ditto.

June 1.—Ditto; the magnetic needle much affected.

Sept. 8.—A severe shock.

Sept. 14.—A slight shock.

Sept. 30.—Ditto.

The whole of the above, without exception, were from south to north, and oscillating from east to west. It will therefore be observed that earthquakes are subject to laws of action as uniform as other natural phænomena.

I could add also more recent observations showing similar uniformity; and on reference to the description given of the earthquakes which occurred in Chili in April last, we find that they were propagated from the south and terminated on the coast of the Caribbean sea.

In 1797, the district around the volcano of Tunguraqua in

Quito, during one of the great meridional shocks, experienced an undulating movement which lasted four minutes. At the foot of the Paramo the earth was rent open, and streams of water and fœtid mud with fish poured out, overflowing and wasting everything. During several of the eruptions which have taken place since the year 1822, on the western coast of Chili, some were seen which were followed by great whirlpools, as if the sea was pouring into cavities of the earth. The volcanoes of Nicaragua, in Guatimala, during their activity, are commonly attended by whirlpools. Had there been such an igneous nucleus as the one assumed by the Plutonists, covered only by a thin crust, what would be the consequence when the sea happens to pour into it? There would certainly follow some awful catastrophe; but we are happy to state no such convulsions have occurred. Aqueous products and muddy matter are more common than lava or melted rocks; and we find that they generally contain putrid fish of the adjoining sea or lakes, as the case may be. Hence, if we take the products, their effects, and linear actions into consideration, we have strong evidences in favour of considering the whole phænomena due to electro-magnetic action. When we examine the volcanoes in Europe we find them governed by similar laws. Etna and Vesuvius are situated on the same meridional line.

Upon glancing at any of the maps of the world, or a globe, it will be observed that the whole of the volcanic groups of the Pacific, the Atlantic, &c., are ranging along the main S.W. and N.E. splits, or their transverse fractures.

With respect to the products of volcanoes, we find them all more or less alike. The Javanese volcanoes frequently discharge large quantities of acidulated waters, even in torrents, with sulphurous mud, being probably the effects of the decomposition of sulphuretted hydrogen gas. Torrents of water issued out of Vesuvius during the eruption of 1631, and from Etna in 1755.

In regions such as Iceland, where the products of the volcanoes have been carefully examined, the same law prevails. They may be traced from a mere spring to a gigantic cone. Professor Bunsen has pointed out several which he considers to be now in progress in Iceland. "The Icelandic mineral springs," he remarks, "to which belong all the system of geysers, may be divided into two main groups, according to their chemical properties, one of which comprises the acid and the other the alkaline silica springs." Sir George Mackenzie mentions that the deposits from geysers extend to about half a mile in various directions, with a thickness of more than 12 feet. The leaves of birch and willow are fossilized, every fibre being discernible. Grasses, rushes and peat are in every state of petrifaction. Dr. Black found the waters from the geysers, both hot and cold, to contain soda, alumina, silica, chloride of sodium and sulphate of soda. The hot springs of India, not situate in a volcanic country, contain from 20 to 30 grains of solid matter in a gallon; silica, chloride of sodium, sulphate of soda, carbonate of soda, pure soda, &c. In short, the eruptive pores, from the size of a small spring to that of the magnitude of a volcanic crater, vary only in their dimensions, and not in character, and are the effects of active local conditions generated by the elements of the sea and the crystalline base; their periodical activity being governed by physical causes resulting from polar tension. The thermal group to which the geysers belong are from south to north, bearing slightly to the E., 20 miles long, and almost parallel with the chain of Hecla, and with the general bearing of the cleavage and splits.

The water of the Great Geyser contains, according to Dr. Sandberger's analysis, silica, carbonate of soda, carbonate of ammonia, sulphate of soda, sulphate of potash, sulphate of magnesia, chloride of sodium, sulphide of sodium, carbonic acid, &c. These compounds and their gases must decompose some of the rocks they pass over, and vary in effects under different conditions, as already described in the previous chapters. There are about 175 known active volcanoes; with the exception of five or six they are situated near the sea, or at least are more or less connected with the saline waters of the ocean, as already explained in the preceding chapters; there are scarcely five of them purely igneous, producing only melted rocks or vitreous lava. Mud volcanoes and gaseous exhalation are the most numerous.

With respect to those which discharge gases, they are not only found connected with volcanic regions properly so called, but also in localities where the cause of the phænomena may be examined, so as to remove any doubt on the subject. Coal districts discharge such continuous streams of carburetted hydrogen, as to afford a sufficient supply for economical purposes. These natural evolutions of gases furnish light and heat in many places, as in the United States, in China, and near the borders of the Caspian Sea. These gases are commonly seen issuing out of coal seams, bituminous beds, and other carbonaceous shales of the sedimentary series, from which the hydrocarbon and paraphine oils are obtained by slow distillation at low temperatures. These gaseous emanations are not confined to coal districts, but are also seen in the sandstone and slaty formations, and in the outcrop of the crystalline rocks, in which are seen bituminous and oily springs, forming in some places large lakes like that of the pitch lake of Trinidad.

It is somewhat difficult to decide in all cases whether these solutions of hydrocarbon are the products of decomposed vegetable and animal matter, or the combination of the primary elements; but, be this as it may, there can be no doubt whatever but that these carbonaceous liquids saturate the shaly sedimentary seams, and slowly widen and crystallize them after their deposition; and ultimately convert them into coal-beds. Coal seams, as they are seen, could not possibly be formed by the direct deposition of vegetation; nothing but petroleum or *liquid* substances could account for the geometrical uniformity of the seams of the coal measures.

The sea contains oily matter: the Kimmeridge beds seem to have been impregnated with marine and fish-oils. Hence we find that the surface of our globe is more or less saturated with liquids, oils, and gases; that these are in a constant state of activity and, in connexion with the deposits of sand, clay, and calcareous substances, form the principal carboniferous and other sedimentary formations of the globe*.

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* The nature of the soil and of the sedimentary beds has much influence on the absorption of the oily substance; thus, whilst a clayey soil slightly laminated, enclosing decayed leaves, favoured the absorption of oil or carbonaceous liquid, the action would be but slight in dry sand.

The absorbing seams, necessarily, gradually increase in thickness, and become ultimately converted into crystalline coal; the original clay forming the beds occupying but thin seams of shale in the coal. (See page 158.)

CHAPTER XX.

THE NORTHWARD UNDULATING MOVEMENTS OF THE EARTH'S SURFACE *EN MASSE* BY THE CONTINUAL CIRCULATING ACTION OF THE MAGNETIC FORCE FROM SOUTH TO NORTH.

THERE is nothing permanent on earth. The minerals and the rocks, the islands and the continents, the rivers and the seas, and all organic nature, are perpetually changing. Nevertheless, the laws by which these changes are being governed are unchangeable, and only require to be studied to comprehend their general character, and to admire their sublime and harmonious order.

If we regard only the conditions of the beautiful and varied organic covering of our globe, the certainty of constant changes is ever before us. The primary elements feed vegetable life, this again nourishes the animal, and both perish to feed the future plant; thus all substances are rendered ever active in the economy of nature to the end of the world. The earth itself is subject to the same laws of mutation; and this was known of old.

Pythagoras taught, 2350 years ago, that "the surface of the earth was ever changing: solid land had been converted into sea, and sea changed into dry land. Marine shells lie far distant from the deep, and the anchor had been found on the summit of hills. Valleys had been excavated by running water, and floods had washed down hills into the sea. Peninsulas had been divided from the mainland, and had become islands."

Plato remarked that the world changed its superficies in every respect; that the heavens and the stars changed and apparently reversed their movements by time, in such a way that the sun appeared to rise on the left instead of on the right. The Egyptian priests informed Herodotus that "since the commencement of the dynasty of their kings the sun had changed its course." Now in the southern hemisphere the sun rises on the right, whereas when we arrive in the north of the tropic, the sun then appears to rise on the left.

"The changes of the earth," says Aristotle, "are so slow in comparison to the duration of our lives that they are overlooked; and the migrations of people after great changes, or their removal to other regions, cause them to be forgotten. The distribution of land and sea in particular regions does not endure throughout all time, but it becomes sea in those parts where it was land; and there is reason for thinking that these changes take place according to a certain system, and within a certain period. The same tracts, therefore, of the earth are not, as some imagine, always sea, and others always continents; but everything changes in the lapse of ages." "Turtles," remarked Dr. Hooke in 1705, "and such large Ammonites as are found in the rocks of Portland seem to have been the productions of hotter countries; and it is necessary to suppose that *England once lay under the sea within the torrid zone.*"

These observations show that the ancient philosophers were well acquainted with the changes going on on earth, and that they indicated movements in the geographical positions of lands. Hence the lands may be compared to the gigantic American rafts, floating with their gardens and habitations from clime to clime, their movement thus causing the apparent celestial changes which have been observed from time immemorial.

These terrestrial changes, though scarcely perceptible from one generation to another, become eventually so great as to alter, not only the relative height of the dry land and the ocean, but also the *latitudes* in the course of centuries.

The changes observed on the coast of South America, in the Atlantic and the Pacific, abundantly testify that they take place by means of a slow subterranean action, independently of earthquakes. Hence the configurations of the coasts are perpetually altering. Two hundred and seventy years ago Sir Francis Drake, with his fleet, entered Albemarle Sound through Roanoke Outlet, which is now a sand-bank above the reach of the highest tides. Only ninety years ago it was navigable by vessels drawing twelve feet of water. In South America the changes are comparatively so rapid as to require constant surveys for the safety of navigation. Since the Spanish conquest the changes have been very considerable, not alone in the elevations and depressions of the coasts, but also in the *latitudes*. The Nova Scotia coal-measures, like the Portland formation in England, contain tropical trees *rooted* in the argillaceous beds. The fossiliferous trunks are surrounded with the fallen leaves of the calamites, ferns, and the remains of tropical reptiles, thus proving that they flourished and died on the very spot where they are now found when that land was within the tropics. The apparent changes in the relative position of the heavenly bodies correspond with the movements observed on earth. The "Precession of the Equinoxes" is 50″ per annum in a north-easterly direction.

"The amount of the motion by which the equinox travels on the ecliptic is, it is true, an extremely minute quantity, but which, by its continual accumulation from year to year, at last makes itself very palpable, and that in a way highly inconvenient to practical astronomers, by destroying, in the lapse of a moderate number of years, the arrangement of their catalogues of stars, and making it necessary to reconstruct them."

"The movements of *precession* and *nutation* are common to all the celestial bodies. Did they only affect the stars, it might be urged that they arise from a real motion of the starry heavens; but since they also affect the sun, moon, and planets, the idea falls to the ground, and there only remains, then, *a real motion in the earth by which they can be accounted for.*" (Herschel, 'Astronomy.')

This supposed cause of the phenomenon of the "Precession of the Equinoxes" was "first suggested by Newton, who attempted to explain it as the result of the form of the earth, and the unequal attraction of the sun and moon on the unequal masses of matter at the equator and the poles, producing a slow *reeling* motion of the earth bodily from east to west, and the recession westward of the equinoctial points."

When this idea was first suggested, little was known of the operations of terrestrial magnetism from pole to pole, and much less of the movements and the undulations of the land, which are now well-established facts founded on geological researches.

The *reeling* motion was purely imaginary, unsupported by any physical observation. Eminent astronomers are now compelled to confess that "Newton's postulate could not be shown to be conformable to the observed facts; and, further, that it even involved a mechanical principle which was fallacious." The first who gave an apparent consistency to the conical or reeling hypothesis was D'Alembert. He founded his ideas on the equilibrium among the forces destroyed, when any change of motion is produced, &c. La Place, again, followed the investigation, not on new data, or any physical ground, but simply on assumed mathematical formulæ; and thus the present curious theory of the "Precession" has been entertained to this day, on calculations which M. Poinset justly repudiates, as being neither in accordance with facts nor capable of giving satisfactory solution of the phenomenon. Hence as the *reeling* theory is groundless and untenable, and is now ignored by eminent mathematicians; and as we have direct and innumerable proofs of the movement of *the surface of the earth*, to account for the phenomena in accordance with all the changes, celestial and terrestrial, nothing but absolute prejudice can possibly resist the acceptance and adoption of the electro-magnetic principle.

Is the "Precession," then, produced by the movement of the *surface of the earth*, which geological inquirers have proved to be in motion? or can the change be accounted for satisfactorily by means of *the assumed conical motion of the earth's axis*?

The only means by which we can determine our geographical position on earth is by reference to celestial objects; as it is impossible to measure and fix the parallels of latitudes on earth by measurements from the terrestrial poles, as we do on artificial globes. We are, therefore, compelled to take the fixed stars as starting-points; and if we take those passing our zenith, which are free from any errors arising from refraction, we find that an annual change takes place equal in round numbers to 50″ in a westerly direction, and 20″ of latitude north. Since the earliest catalogue on record (that made by Hipparchus, 2140 years ago) we find, by observations, that the entire surface of our globe has moved to the north-west in a spiral path 30°, and northward 12°; and this terrestrial change has affected the "equinoxes," that is, the apparent intersection of the plane of the ecliptic with the equator, to a corresponding amount. Hence by means of this well-known phenomenon called the "precession of the equinoxes," we are able to determine to a second of a degree the rate at which the lands are moving northward by means of the polar force. Attempts, it is true, have been made to account for this phenomenon by means of a conical movement of the terrestrial axis; but this hypothesis, which was first rendered plausible by D'Alembert's speculations, has been recently repudiated by M. Poinset (an eminent French mathematician) as untenable and totally unsatisfactory. M. Poinset, however, was not able to bring before the Institute any satisfactory hypothesis as a substitute, founded on physical data, to solve the problem. We have now a very great advantage over our predecessors; we can study every part of the globe *as it is*, the changes and the direction of the movements, and thus arrive at a safe conclusion founded on observed facts, not being compelled to *imagine* conditions to suit any given mathematical hypothesis.

The real conditions of the world are now well known, and we have to account for them as they really are, and not as they were *supposed to be* in the time of Kepler, Leibnitz, Newton, D'Alembert, and La Place.

We have referred to the undulations of the surface of the globe, and to the lands having been raised from the deep. We have also incontrovertible proofs that the lands have not only been raised from the bed of the ocean, but likewise have been *gradually brought from the tropics towards the Arctic regions by the continuous northward action of the polar force,* inasmuch as the lands of the northern hemisphere contain the organic remains of the torrid zone. Hence, if the evidence of marine remains compels us to admit that the lands must have risen from the sea, upon equally demonstrable data we maintain that the lands of the northern hemisphere, which contain tropical remains, *must have been brought there from the torrid zone.* The latter conclusion is necessarily as self-evident as the former. The so-called crust of our globe moves spirally round the axis, in such a manner as to make any given point on earth to approach at the rate of twenty seconds of a degree per annum towards the north polar basin. In other words, the semi-aqueous crystalline film of our globe has a kind of molecular spiral action from S.E. to N.W., which makes any given spot of dry land to progress and get nearer the Arctic region about 20″=to three furlongs per annum, thus causing the changes, and the remains of different climates to be brought to the north.

The certainty of this terrestrial polar movement has been long established, and demonstrated by astronomical observations. Let us, as an example, take γ Ursæ majoris as a star from which to measure our geographical position. The position of this star is highly favourable for making observations in this latitude, inasmuch as it passes within 3° of the zenith, and therefore may be considered as unaffected by refraction on its transit in the meridian.

In January 1853 this star's transit was 3° 2′ 5″ to the north of the zenith of Greenwich. In January 1864 its meridional transit was only 2° 58′ 24″ to the north of Greenwich; and in 100 years hence the Greenwich zenith will be only 2° 25′ 4″ south of it. In 435 years hence γ Ursæ majoris will be in the zenith of Greenwich, or, in other words, the Observatory will, in the interim, have progressed northward equal to that amount. This being a demonstrable fact, it follows as a natural consequence that England must have been within the tropics about 6000 years ago, and will be carried into the inhospitable and decomposing basin of the north in less than 3000 years hence.

In the Introduction, page lxxiv, it is stated that the spot on which London is situated must have been in the equator about 9180 years ago. This calculation was founded on the assumption that the surface never moved at a greater rate towards the north than 20″ during that period. If we take the miracle of the universal flood into consideration, and give it its due weight, the surface, under the influence of the intense action then put in force must have been greatly changed, and was probably carried many degrees northward during the period of submergence. The antediluvian tropical lands might have been propelled northward to the temperate zone. We have no reason to suppose that the Ark descended on the same land as that from which it ascended by the waters of the Flood. On the contrary, it would be more reasonable to conclude that it was a new land just emerged from the deep. Hence England might have been situated in the equator only 6000 years ago, or even less, if we admit the probability of a more rapid polar movement than 20″ north during the days of the Flood.

Again, if we find no other relics or organic remains in the oldest land seen on earth (viz. Greenland) than such as those which belong to similar plants and animals now flourishing in the north of Africa, nor yet in England, but such organic remains as might have flourished on the northern margin of the tropics, we have no demonstrable data by which we could, even at the slow normal rate of 20 seconds per annum, maintain that the globe *must be older* than 7000 years upon this hypothesis*.

CHAPTER XXI.

THE NORTHWARD MOVEMENT OF THE SURFACE PROVED BY THE CLIMATE OF THE LAND IN THE NORTHERN HEMISPHERE GETTING COLDER.

We have evidences of the progressive movement of the surface towards the arctic region in the changes of the temperature of the northern hemisphere.

Within the limits of the historic records we find that the climate of Europe has been getting gradually colder, and that the inhabitants of the north are continually migrating southward. We mean here the annual *mean* temperature, and not the mere periodical cold or mild seasons. The character of the vegetation is the best test on this question. The first settlers in Iceland found extensive districts of that now dreary country covered with forests of birch and fir. They were also able to cultivate barley and other grain. At present the whole island is almost a naked desert, the native woods have totally disappeared, and the Icelanders have long since relinquished the practice of growing corn. The relics of the past in this island are few, but sufficient to prove its former habitable state. One of the most remarkable circumstances attending the discovery of Iceland is, that relics were found there which showed that it had been *previously* inhabited. The nature of these relics, which consisted of bells, wooden crosses, and books in the Irish character, induced the Norwegians to believe that those prior inhabitants were Christians, who gradually retired southward to Scotland and Ireland.

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* The continuous action of the polar force must change the entire surface of the earth, from the Antarctic to the Arctic circle, in less than 22,000 years. The age of the earth *may* be only about 7000 years, but we have no date to show that it *must be greater* than 22,000 years old, as all the surface of the globe would be entirely changed in the interim.

The most ancient of the Icelandic chronicles are not contented with mentioning the vestiges of former inhabitants; they distinctly state that there were actual settlements on the island previously to the Norwegian emigration*. They name Kirkinbui, one of the *warm* and *fertile valleys* that occur on the southern coast, as the residence of those *papæ*, as they called strangers, who deserted the island.

Greenland, according to most of the Icelandic histories, was discovered in 982, but it was then inhabited; and there exist letters patent of Louis the Debonaire in 834, and a bull of Gregory IV. in 835, which confers on the church of Hamburg, among other privileges, that of converting the heathen in Iceland and in Greenland, which at that period contained large populations.

The new settlers in Greenland had their bishops from Europe, and continued their intercourse with the parent state of Norway till the year 1418. The colony paid to the pope an annual tribute of 2600 pounds weight of walrus' teeth, as tithe and Peter's pence. The dreadful pestilence, called the *black death*, which in the middle of the fourteenth century depopulated all Europe, extended its ravages to Greenland. The colony was, from this and the increased severity of the climate, enfeebled, and soon after disappeared from history.

There was a country called Vinland within a few days' sail of Greenland, watered with rivers yielding abundance of fine salmon, on the banks of which were trees loaded with agreeable fruits, the temperature delicious, and the soil very fertile. Amongst the fruits were found grapes, which was the cause of their naming it the *land of wine*. It is impossible to shake the authenticity of the above circumstantial accounts of the Northmen; and it is likewise difficult to acknowledge their genuine character without admitting at the same time that Vinland was in Newfoundland.

Wine was made from grapes which grew formerly in the open fields of England and in the north of France, and there are ample proofs of a similar reduction of mean temperature in other parts of the continents of Europe and in North America. It is in the *northern* regions that we find relics of the past so abundant, and more especially of man and his works, and the remains of animals subject to his control, and probably the greater part of these have disappeared, by the constant wearing away and oxidation of the land as it approaches the pole.

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* Lardner's Cyclopædia, Maritime Discovery, vol. i. p. 216.

According to recent accounts, several subterranean stone labyrinths have been discovered in Lapland, Nova Zembla, Spitzbergen, and some of the islands lying near the coasts of Finland, particularly in Wiez, which is all desert, called by the natives Babylons*. Arabian coins are found in many parts of Russia, along the Volga, and northward even as far as the White Sea, all of which are of a date anterior to 1010†; thus showing that the different races gradually retrograde southward as the dry land advances northward.

When we descend below the surface and examine the remains of the past organic system now inclosed in the rocks, the proofs of the change of climate are much more decisive, and free from all the doubts arising from imperfect history. So striking has been the general northward action on the surface, that the effects have been long observed. In the northern latitudes beyond 60° we find the animal spoils of the southern countries and the marine exuviæ of the southern seas embodied in the rocks; but in the southern latitudes we find no remains of animals, vegetables, or shells belonging to the northern, but those only indigenous to the neighbouring land and seas. The sedimentary rocks of the northern hemisphere were, at a former period, during their deposition, exposed to hot climates, and gave nourishment to forests of luxuriant plants. In the superficial deposits of sand, gravel and loam, strewed over all parts of Europe, remains of Mammalia are discovered, among which are those of the elephant, rhinoceros, hippopotamus, bear, hyæna, lion, tiger, crocodiles, and others, consisting of genera now confined to the tropics.

At the period of the deposit of the Lias the vegetation was similar to that of the *southern hemisphere*, not alone in the simple fact of the presence of Cycadeæ, but the pines were also of the nature of species now found *only* to the *south of the equator*. Of the four recent species of Araucaria at present known, one is found on the east coast of New Holland, another in Norfolk

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* Athenæum, part 190.

† Lardner's Cyclopædia, Maritime Discovery, vol. i. p. 169.

Island, a third in Brazil, and the fourth in Chili. With regard to the degree of analogy which the productions of different regions may be found to present with the fossil reliquiæ of the lower series of rocks, it is impossible to turn to Australia without observing most distinctly that the productions of that region have more than the average resemblance to the fauna and flora now found entombed in the northern hemisphere. In the coal deposits the proofs are equally striking that they were deposited in a climate like the southern hemisphere*. No coal except a recent formation of lignite and bituminous matter is found from the tropic of Capricorn southward, *i. e.* of the character and magnitude of our great coal formations; in a word, the whole of the deposits of the southern hemisphere are comparatively recent, whereas those of the northern are more or less ancient.

It is not merely by reasoning from analogy that we are led to infer a diminution of temperature in the climate of the lands now situated in the northern hemisphere; there are direct proofs in confirmation of the same doctrine. It is not in England or Northern France, but around the borders of the Mediterranean, from the South of Spain to Calabria, and in the islands of the Mediterranean, that we must look for conclusive evidence on this question; for it is not in strata where the organic remains belong to extinct species, but where living species abound in a fossil state, that the question can be subjected to the *experimentum crucis.* The fossils of the Subapennine hills, and their living analogues from the tropics, correspond in size; but the individuals of the same species from the Mediterranean are dwarfish, and appear degenerate and stunted in their growth, for want of conditions which the Indian Ocean still supplies. This evidence is not neutralized by any facts of a conflicting character; such, for instance, as the association, in the same group, of individuals referrible to species now confined to the arctic regions. Whenever any of the fossil shells are identified with living species at or near the equator, it is not in the Northern Ocean, but in the Southern that they must be sought.

In Chili, in latitude 36° S., the shells found on the tops of the mountains are those of the neighbouring sea. Those found on the hills between Suez and Cairo are similar to those of the Indian Ocean; and those that exist in the calcareous rocks of Egypt are likewise analogous to those living in the southern seas.

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* The description of the flora enclosed in the coal formation of England so exactly corresponds to that of the existing flora of the southern hemisphere, as to render the analogy complete, as also all other organic remains.

When geologists assumed an igneous globe undergoing refrigeration, to account for the former high temperature of the northern hemisphere, they imagined that the southern hemisphere indicated the same kind of change, *i. e.* from hot to cold; but it will be observed that the changes are quite the reverse.

The variable temperature on the surface of the globe is produced by solar radiation in connexion with the modifying effects of the atmosphere: we have no reason to suppose that climate and the organic kingdom have ever been governed by any other source of heat. In order to understand the general nature of the present climates from pole to pole, let a convex lens be exposed to the rays of the sun, the rays will be concentrated into the focus, and cause intense heat; the degree of heat depends on the number of rays collected and concentrated into the focus. If we expose a small point to this focus it would be intensely heated; but if, instead of a point, we place a large body in the focus, the heat would be diminished, and the nearer we approach the lens the less the heat.

Our globe occupies the focus of the atmospheric lens, illustrated in Plate III., and thus prevents the concentration of the sun's rays into one point. In the equatorial region, when the sun is in the zenith, if we ascend to the height of 20,000 feet, instead of finding it hotter as we rise, we get into colder regions, *i. e.* perpetual snow. Hence it follows that one planet may be near the sun, and another placed at the confines of the solar system; and yet both possessing equal temperature on their surfaces, by proportioning the diameter of their atmospheric lenses to that of their respective bodies. Therefore to say that Venus *must* be intensely hot and that Saturn is in the region of eternal snow, is a mere assumption, unsupported by analogy. Some attempts have been made to show how the globe may have become hot and cold by its probable exposure to the effects of intense stellar radiation in passing through the milky way; but such speculations are flights of fancy, and unworthy of attention. There has been too much dependence placed on celestial observations and assumptions already for the progress of geology. If we would speculate to any purpose on a former state of our globe, and on the succession of events which from time to time have changed the condition and form of its surface, we must confine our principal inquiries to the results or effects of terrestrial physics, and not attempt to solve the problems by reference to celestial objects; for if we differ so materially on those points which we can handle, it is not probable that we can decide by referring to objects so much beyond our reach.

We shall give a few examples of some points used by geologists for their guidance in theoretical researches, founded on astronomical observations, which are not only doubtful, but proved incorrect. It is said that the moon turns on her own axis, because she is an oblate spheroid, notwithstanding that she always presents the same face towards the earth. That a body revolving round a centre, and continuing to present *the same face to that centre,* should rotate on an axis situated parallel to the revolving axis, is physically impossible. Yet it is maintained, and absolutely stated in our astronomical works, that the moon rotates on her axis.

Suppose a balloon were to float around the earth, it would continue to present the car towards the centre, in the same manner as a vessel would her keel in sailing; yet neither can be said to have rotated on their axis in making the circumnavigation*.

There is another idea propagated respecting this body, viz. that she has no atmosphere, because we do not observe any refraction during the occultations of the stars. If the moon is enveloped in an atmosphere, the angle of refraction would be between the moon and the star, and that would, on impinging on the moon's surface, be reflected towards the earth. If a ray of light be successively transmitted through several transparent media having different refracting powers on one side, and reflected so as to pass through similar media on the other side, its emergence from the last of these media will take a direction parallel to that which it had when incident upon the first of them. In this case the several refractions which the ray suffers in passing through the media on the one side is compensated and neutralized on the other, so as to produce, on the whole, no deflection of the ray from its original course. "The angle of incidence is equal to the angle of reflexion." The reason why we observe the refraction of the rays in our atmosphere is, because we are exposed to *one* angle only, *i. e.* that of refraction, owing to our being *within* the spherical media. Yet we are told the moon has no atmosphere, because she does not show signs of refraction. Persons have actually attempted to describe the geological features of the moon, being at the same time comparatively ignorant of the nature of the ground on which they stand! If the above simple questions are in such a confused state, and so easily demonstrated at a distance by the aid of mathematics, what are we to expect from the geology of the moon?

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* The governor balls of a steam-engine make analogous movements, and in looking at them it will be at once perceived that they merely revolve around a centre, and do not rotate on their respective axis.

The changes of climate have been attributed by some to a greater eccentricity of the orbit formerly than it has at present. But even the eccentricity of the orbit is a doubtful question; the only proof brought forward that the orbit is eccentric is the variable diameter of the sun. The atmospheric lens not only refracts the rays when not in the direction of the radius, *i. e.* in the zenith, but also augments the size of bodies, such as the sun, the maximum size being in the horizon and the minimum in the zenith. According to a series of observations made by the author for 13 years within the tropics, the sun's *apparent* diameter is throughout the year the *same* when measured in the zenith; therefore its observed variable diameter is an *optical deception,* and not from any eccentricity of the orbit. That this is the case must be well known to those who have taken observations in the southern hemisphere with delicate instruments, and especially when the diameter of the sun formed an important amount in the measurement. See Plate III.[*]

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[*] Santa Ana, N.L. 5° 10′ 0″. The sun's diameter, according to direct observations taken in the meridian from the south tropic to the north.

South tropic	<61°	22′	37″	altitude.	31′	30″	diameter.
Equator	84	50	0	,,	30	45	,,
Zenith	90	0	0	,,	30	36	,,
North tropic	71	35	20	,,	31	12	,,

The following measurements exhibit the apparent variation of the sun's diameter

To return from this digression, we find that the variable nature of climates from pole to pole arises principally from the obliquity of the rays and the height from the sea, and not from internal heat; therefore we can only account for the changes of climate indicated by the organic remains by changes in the relative position of the dry land and the sun's rays.

"However constant," says Sir C. Lyell, "may be the relative proportion of sea and land, we know that there are constantly some small variations in their respective geographical positions, and that in every century the land is in some parts raised and in others depressed. By these ceaseless changes the configuration of the earth's surface has been remodelled again and again since it was the habitation of organic beings, and the bed of the ocean has been lifted up to the height of some of the loftiest mountains. The imagination is apt to take alarm when called upon to admit the formation of such irregularities in the crust of the earth after it had once become the habitation of living creatures; but, if time be allowed, the operation need not subvert the ordinary repose of nature, and the result is in a general view insignificant, if we consider how slightly the highest mountain chains cause our globe to differ from a perfect sphere. Chimborazo, though it rises to more than 21,000 feet above the sea, would be represented, on a globe of about six feet diameter,

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in the plane of the orbit during its daily apparent path, from the rising to the setting; the latitude of observations and the sun's declination being equal.

		Diameter.			Diameter.
The sun rising <	0°	32′ 55″	Noon S. in zenith <	90°	30′ 36″
,,	15	32 35	,,	75	31 2
,,	30	32 18	,,	60	31 30
,,	45	31 55	,,	45	31 50
,,	60	31 32	,,	30	32 15
,,	75	31 6	,,	15	32 32
			The sun setting ...	0	32 51

If it is maintained that the orbit is an ellipse, because the sun appears larger at a lower altitude in December than in June at a higher elevation; on equally good data we may state that its diurnal path is an ellipse, and that our approach to the sun morning and evening is compensated by the obliquity of the rays and greater velocity, thus forgetting the consequence of such deductions at those places under the sun in the opposite hemisphere. When Kepler established the eccentricity of the earth's orbit little was known of refraction.

by a grain of sand less than one-twentieth of an inch in thickness."

Let us consider what would be the nature of the deposition in a large tract of land like Australia, gradually propelled by the permeating forces from its present position to the north polar region. Here and near it, tree ferns, Cycadeæ, Araucariæ, Cassiarinæ grow upon the land: corals and sponges abound on the coast even of Van Diemen's Land; also Trigonia, Cerithium, Isocardia, a Cardium like *C. hillarium* of the greensand, and quadrupeds of the peculiar marsupial races, to which the Stonesfield animal is referred by Cuvier. These would be deposited in the depressions, and their place would become by degrees occupied by others as it approached the equator, where it would be inhabited by a different variety. These would again retrograde southward and disappear on the arrival of the land in the north, and their place would be taken by others from more northern zones. The contents of the deposition, supposing the land undulated, as it does at present, above and below the level of the sea during its movement from the south to the north, would represent the order of deposition and organic remains in the exact order they are now found in the rocks of the northern hemisphere, viz. the first sediment enclosing the remains of the southern zone; the second the tropics, and the third the northern hemisphere.

CHAPTER XXII.

ON THE POSITIONS, UNDULATIONS, CONTORTIONS AND FRACTURES OF THE SEDIMENTARY ROCKS.

THAT subterranean forces have acted on the sedimentary rocks during and after their formation, is abundantly proved by their general appearance in all parts of the world. We have shown that the surface of the crystalline rocks and the beds deposited on them have been cleaved, fractured and dislocated, and that there is scarcely an area of a few square miles which does not bear marks of having been disturbed and altered by chemical forces. Since this is the case, it is reasonable to suppose that the sedimentary beds must be subjected to many changes by the constant but insensible slow action of the polar crystalline forces. This power being perpetual, alters the plane of the beds by numerous undulations and different relative positions during their depositions; so that a series may commence to be deposited on a concave, half formed on a level plane, and completed on a convex surface; sometimes receiving the elements on the one side, and again on the other, according to the nature, amount and continuity of the undulations.

Suppose, for instance, we examine a series of rocks in the northern hemisphere, and find them to contain in the ascending order, first, beds with organic remains belonging to the south temperate zone; another series of beds inclosing marine and terrestrial animals corresponding to those of the tropics resting on them; and again, beds of marine and freshwater shells alternating, similar to those now living in the northern hemisphere, completing the series: it would be very evident that such a deposition must not alone have taken place during different periods, but likewise in different climates, and consequently such a formation would show that the beds must have undergone a considerable oscillation since the commencement of their deposition. The series, in moving from zone to zone, would be governed by the local nature of the base on which it rested, and would necessarily conform to all the changes which may periodically occur in the inferior bed. One of the most satisfactory results arrived at in the study of the sedimentary rocks, is the certainty that the subterranean movements were not all of the same date, and that some rocks had been bent and disturbed before others were formed.

Let us suppose a coal formation to be now forming near the mouth of the Rio de la Plata, and the movement *en masse* northward to be 20 seconds per annum, it would take 2200 years to arrive within the tropic of Capricorn; during this period there would be very considerable changes in the configuration of the land; and when we consider the longitudinal extent of the movement, say about 750 miles, we need not be surprised that the mass should happen in the interim to be much contorted and elevated or depressed a few thousand feet from its former relative position. From the tropic of Capricorn to the equator the sedimentary mass may remain above the level of the sea and form the habitation of the organic beings confined to that part of the earth, whilst another mass of the same age may still remain under water. From the equator to the tropic of Cancer it may become again submerged below the level of the sea, and thus receive additional layers of sedimentary beds; on its emergence from the sea in the northern hemisphere, it would present an undulated compound, containing a different series of organic remains belonging to distinct zones, with one strong line of demarcation, showing the absence of the beds belonging to the south tropical zone, arising from its being then above the sea level. It will, therefore, be observed, that although the sedimentary series of rocks are commonly described as if they were regularly built on each other in the following order, Cambrian, Silurian, Coal formation, Lias, Oolite and Chalk, with a series of beds called Tertiary, they are never found so complete in nature. It is true that the order of the beds is never found inverted, yet a great number are always absent, and their respective developments vary considerably in different localities. England contains almost all the series from the south frigid to the north temperate, not piled on one another, as described in the usual geological sections, but overlapping at the edges at different extremities of each other, thus showing that although some parts were constantly under the sea receiving new deposits, they were not always the same, but alternately changing according to circumstances. In reading some geological works it may be supposed that the earth was once actually covered by all the variety of beds, like the concentric coats of an onion; but such an idea is very erroneous; it is abundantly evident that many of the deposits were local.

In order to give a more general idea, and comprehend the relations of superposition of the sedimentary rocks, as actually observed in the different zones from south to north, and to show that although the order is never inverted, the beds are often wanting, and seldom seen in their complete numerical order, we shall enumerate the series in the following manner:—

Deposits.	Contents.	Geological names.
1. South frigid zone.	Trilobite, Orthoceratite, &c.	Cambrian and Silurian.
2. South temperate.	Terebratula, Producta, Encrinite, Spirifera, &c.	The great coal formation.
3. South tropic.	Ammonites, Belemnite, Gryphite, &c.	Oolite.
4. North tropic.	Echinus, Fusus, Pecten, &c.	Chalk and clay.

1. Commencing our examination south in Patagonia, we find, by a transverse section from Rio Santa Cruz to the base of the Cordilleras, and another on the Rio Negro, that the whole sedimentary series is of recent origin, and irregularly covering the primary rocks. The shells and corals of the lowest deposit are those which belong to the bordering sea. Scattered over the whole, and at various heights above the sea, from 1300 feet downwards, are recent shells of *littoral* species of the neighbouring coast, so that every part of the surface seems once to have been a shore, thus indicating a very gradual elevation. In this part of the globe we only find irregular recent beds of No. 1. The fossils of Tierra del Fuego and Falkland islands can hardly be distinguished from many of the species found in the Silurian rocks of England.

2. *The south temperate.*—In the Brazils we find isolated masses of No. 1, with occasionally thin beds of No. 2. In Australia, on the eastern coast, a similar series has been observed.

3. Near the equator, according to the section, Plate VII., embracing the three Cordilleras, the following numbers will represent the variation in the ascending order of the sedimentary beds:—

Sedimentary . .	3			3	3			3		
	1	2	1	2	1	3		1	3	
Primary	0	0	0	0	0	0	0	0	0	0

This enumeration furnishes an easy method of indicating the equivalent beds, apart from their relative ages in the different zones, and also the local suppression of some of the series.

4. *North tropic.*—The sedimentary rocks of this zone are similar to the preceding, but much more developed. In the north temperate zone these rocks have been well investigated; and we find in the United States and Europe the following order:—

	3	4								4		
Sedimentary .	2	3	4	3			2	4	4	2	3	
	1	1	2	1	4	3	1	2	3	1	1	
Primary	0	0	0	0	0	0	0	0	0	0	0	0

Consequently it follows, that although No. 4 (chalk) covers No. 3 (oolite), the latter is not always formed: either of the series may be deposited immediately on the primary base; and it is necessary to obtain other indications than No. 3 to ascertain the existence of No. 2 under it. However, we know that No. 3 cannot be found under No. 2, nor any other in the inverted order. A deposit may be of the same age and belonging to the same zone, that is, exactly equivalent to another, and yet differ both in lithological and zoological character, and thus cannot be determined without the aid of the inferior and superior beds.

In Ireland, I remember seeing pits being sunk in No. 1 in search of No. 2 (coal) on the eastern side of the Wicklow mountains; although no fossil could be detected in No. 1 to prove that the coal beds could not exist below, yet the structure of the rocks, and their lamination, enclosing veins of quartz and pyrites, were sufficient to show, not only their contact with the primary base, but their actual transition: it was like cutting into the body of a tree in search of the bark. When the upper series of the sedimentary beds are much developed the lower are seldom found underneath, and *vice versâ*. It is essential to bear this fact in mind when making trials for coal below the Chalk, Oolite, &c., as a thick seam of coal could not exist, even had it been originally deposited in the spot, under such a pressure as would be produced by a *complete set* of the European superincumbent series; therefore those who have studied geology from theoretical sections must modify their ideas on this point, and study Nature.

Some geologists have actually attempted to calculate the thickness of the sedimentary series by means of the angle of the planes of cleavage. To deduce the thickness of the earth's crust by the planes of lamination, is like calculating the depth of a transverse section of a tree by the *medullary rays* instead of the *concentric rings*; and must have proceeded from confounding planes of cleavage with planes of bedding.

The more recent deposits must necessarily be less contorted and fractured as a whole than those which are more ancient, on account of their being subject to less disturbances, and not so compact: the fractures and dislocations visible on the surface of any series of rocks would not therefore afford a just estimate of the amount of disturbances to which that particular part of the earth's surface has been subjected. Extensive ranges of country often have the beds of rock of which they are composed thrown into particular lines of direction. Such lines, when considered in the usual manner with reference to our general ideas of distance, appear of considerable length; but when viewed, as they should be, in connexion with the whole superficies of our spheroid, a large proportion of them lose their apparent importance: many of them are then seen to be so short, that the cracks or elevations of strata by which they are marked may readily be conceived to have been effected by comparatively small intensities of force. It is a want of due attention to the relative proportions of the radius of the earth to the height of mountains and the undulations of strata, which is the cause of such disturbances being considered as the result of tremendous igneous forces. Most gigantic and awful igneous eruptions are commonly brought forward to account for disturbances which could be effected by an ordinary hydrostatic press connected with a subterranean sheet of water.

It is a singular fact that the sedimentary beds are principally tilted on the *southern edges* in Europe and America, indicating very forcibly the effects of a northerly action. And we find also that the ridges are principally on the western sides of the continents and islands, and the sedimentary plains on the east flanks.

Movements, fractures and dislocations, of such order, regularity and extent as we find in the whole masses of rocks constituting the surface of the globe, require a corresponding, slow, regular and powerful acting cause, such as that which we find in the operations of terrestrial magnetism. Volcanoes and earthquakes are merely secondary forces, *i. e.* the effects of the subterranean currents; therefore even the local and irregular disturbances from these must be classed under the same natural operation as those above alluded to. It is anything but desirable to have constant recourse to great forces in explaining geological phænomena, when the exertion of a comparatively feeble power will afford sufficient explanation. In coal works, when the workings happen to be very extensive, the lower beds are often seen swelling upwards, and sometimes the upper bulging downwards until they meet, without producing a single crack: here we have contortions of solid rocks by a slow action, without those awful subterranean convulsions and igneous matter to soften rocks, which some are so fond of contemplating. The mere elevation and contortion of mountain masses can be produced by a slow force as well as by other means; and the examination of these upraised mountains shows that the effects could not be produced by one great and instantaneous action. Contortion requires that the rocks should be in a yielding state, and that the particles be capable of a certain movement among each other, so that in applying force no absolute fracture would occur. Were we to attempt to bend a bed of limestone by one instantaneous action, it would immediately break; but if we gradually apply pressure, so slow as to afford time for the constituent particles to adapt themselves to the change, the bed may be subjected to any degree of contortion without fractures while *in situ.* The volcanic forces are insignificant compared with the apparent feeble force of crystallization; it is like the effect of a blow from a sledge on a sheet of ice on a pond, compared with those effects which would be produced by water if confined and connected with an hydrostatic press; the former would exhibit a great break in one individual spot, but the latter would fracture and bend the ice throughout by a slow and insensible action. The disturbances thus produced on the ice would be greater than those observed in the crust of the earth, when viewed in their relative proportions.

When we consider that rocks have been liable to be contorted from the time they were in a state of mud to their consolidation, we can easily conceive why they should present such bends as we now find in them. The extent to which the particles of various rocks, saturated with water as they always are in nature, may be compelled to move among each other by great pressure, has never been sufficiently considered. Indeed rocks have been viewed too much in the sense of dry, hard and inert, instead of active and moist masses: an absolute dry and compact rock would be a phænomenon in nature, *i. e.* an extraordinary exception to the usual natural production.

It is exceedingly difficult to expel moisture from rocks, and when expelled the difference in weight is found very considerable. Limestones contain a great quantity of water, and are sometimes found at great depths very soft; and often, by means of the weight of the superincumbent beds, they force a great proportion of their soft parts into the joints of the bounding rocks. Sometimes limestone beds and hornblende veins have been thus introduced between the planes of sedimentary beds. As this part of the subject has been anticipated by the observations made on the nature of the crystalline rocks, we need not extend them here; we shall conclude by stating that stratified rocks are not homogeneous inflexible dry and solid masses; on the contrary, they are composed of numerous moist and pliable sheets, capable of extension and compression, easily twisted and bent under pressure, the productions of different zones, and are constantly propelled forward towards the north pole.

CHAPTER XXIII.

ON THE ORGANIC PRODUCTIONS OF THE DIFFERENT ZONES.

Those who have the opportunity and capacity of surveying nature with a comprehensive glance, and abstract their attention from local phænomena, cannot fail to observe the great difference which exists in the organic development of the zones of the southern hemisphere as compared with those of the north. According to the ordinary notions, the variations in the degrees of vitality are solely governed from the equator towards the poles by the decreasing strength of the animating heat of the sun, and consequently, the productions of corresponding latitudes, on either side of the equator, are more or less alike; but this is far from being the case.

In order to show the peculiar characteristic difference, we shall give a short description of each zone, so that the reader may be more able to appreciate the cause of so great a difference in the character of the organic remains which we find in the old sedimentary series, and those now existing in the northern hemisphere.

Antarctic region.—Leafless Cryptogamia (fungi, lichens, &c.) are nearly the only species found even on the external margin of this region. This paucity of vegetable species corresponds with the paucity of animal forms. Even in Deception Island (lat. 62° 50′ south) only lichens are met with and no grass, and further south terrestrial Cryptogamia are wanting. Antarctic phanerogamic vegetation is also poorer in species at equal distances from the pole as compared with the north; yet, as we pass to the next zone, the vegetable kingdom becomes at once luxuriant in magnitude, although somewhat meagre in variety; consequently totally different to that gradual transition we observe in the north from the temperate to the arctic zone.

In Sandwich land, 59° south lat., perpetual snow and ice reach to the sea beach; and even in the island of Georgia, 54° south lat., the line of perpetual snow descends to the level of the ocean; and ice has been seen floating towards the equator to the latitudes of 36° and 39° south.

The islands and new continents now gradually emerging in this region are mere barren wastes covered with sea sands, the dung of aquatic birds and shells being scattered over the whole at various heights above the sea, with recent shells of littoral species of the immediate coast, having no traces of terrestrial animals, and entirely different to the old arctic lands with their various beds of organic remains. The next zone presents almost at once a tropical aspect as regards plants, and of the maximum dimensions.

South temperate.—Some of the noblest forms of vegetation are found in this zone, such as the tree-ferns and palms, and advance south to the parallel of 53°: these are scarcely seen beyond the tropic of Cancer in the northern hemisphere. Tree-ferns thrive admirably well at Hobart Town in Van Diemen's Land; also in New Zealand and Campbell Islands. Even in the Archipelago of Tierra del Fuego south, corresponding to the latitude of Liverpool north, vegetation thrives most luxuriantly in large woody-stemmed trees of fuchsia and veronica. That this difference is owing to the influence of the zone, and not the species, is proved by the fact, that plants which are in England annuals, become, when transplanted there, perennials. This has been observed to be the case even with barley, beans, &c. The wheat grows exceedingly high, the stalk being so strong that it has the power of resisting the winds. The myrtle, fuchsia and ferns are timber trees to the lat. of 50° south, and the humming-birds are common in the forest.

South America appears to be the most beautiful portion of the palm world, in consequence of its being situate within the limits of the south temperate zone and connected with the tropics. Coniferæ, palms, &c., still grow together in this region in gigantic dimensions and in profusion, and also in New Zealand and Patagonia; and the marshes are equally luxuriant in succulent plants.

Among the tallest of living trees the Norfolk Island pine is found in south latitude 30°, and not even known in the northern hemisphere. The abundance of moisture and equalization of heat, so peculiar to this division of the globe, stimulate the vital powers of the vegetable world; and again, the nutritious plants, together with the climate, appear to act with equal power in augmenting the size of the herbivorous animals.

In ascending from the vegetable to the animal world, and from one rank of animal existence to another, the most admirable order is manifest. We behold in every region striking instances of the structure of animals being fitted to the productions of the different zones. Limited as this zone is in dry land at the present period of the world, there yet exists the representatives of the former bulky herbivore in the forests, and the remains of the sloths, armadillos, opossums, &c., are frequently found mixed with those of the Megatherium and Glyptodon in Patagonia.

The amphibious reptiles and sauroid fish become also conspicuous as we proceed towards the tropic of Capricorn, both on the coasts of America and Australia; thus presenting an organic aspect totally different to the north temperate.

The degree of development attainable by organic forms, vegetable and animal, is determined by laws which have not been sufficiently studied. We find in each of the divisions of animated nature a gradual diminution in size from the south temperate to the arctic region; the colossal reptiles, saurians, &c. of the south dwindle into mere small lizards as we recede northward; and even man oscillates from a Patagonian or Amazonian giant to an Esquimaux; and such is the case with a very large proportion of the organic kingdom.

Tropical zone.—In roving through the forests in the lowlands of South America, especially between the rivers Orinoco and the Amazon, the earth is so overloaded with thick and gigantic vegetation as to render it impenetrable for beasts. In these regions we consider man as a being not congenial to that order of nature. The earth luxuriates in its gigantic and thick development of plants, and solemn silence prevails, excepting on the banks of the rivers. The crocodile, sharks, boas, &c. are masters of the rivers; the jaquar, pecari, tapir, &c. rove along the banks, and the serpents occupy the high grass; nothing impeding their increase, residing there as in an ancient heritage or primæval world, without fear and without danger. Human beings and domesticated animals are looked at in such a scene as inhabitants of another world. Were this region to sink 320 feet, the whole surface would be covered by the Atlantic Ocean, and the eastern declivity would become again, what it was before, a shore of the ocean. The great oscillations of these countries tend to destroy the larger animals in consequence of altering the physical conditions; hence the larger type becomes gradually lost in the course of ages, while the lesser remains. The Megatherioids of South America have disappeared, but the Sloths have remained, and many races of animals have not only lost the larger types, but deteriorated from the same physical changes. The comparatively diminutive animals of South America, Australia and New Zealand, which are the allies of the gigantic extinct species, have been preserved, like descendants of former races, owing to their being more capable of existing under less favourable physical conditions than the larger animals. The proportion of land now occupying the south tropic and south temperate is far too small to supply the necessities of the larger tribe. It is very probable that Australia was not connected with a tropical continent previous to its emergence; hence the cause of the great deficiency in quadrupeds. The small animals belonging to this region have evidently come from islands, and have accommodated themselves to the narrow limits produced by the changes under which the larger species must have succumbed.

Notwithstanding the power and richness of the vegetable productions within this zone, we often find vast arid tracts surrounded by borders of evergreens—seas of sand, as it were, where no animal could exist; with here and there only a few isolated fan-palms. These great plantless tracts of land, in regions characterized on every side by the most exuberant vegetation, is a geological phænomenon not properly attended to. Humboldt very justly observes, that when once a region loses its vegetable mould, and becomes covered with a thick layer of sand and gravel, many centuries may elapse before the surrounding greens will cover the dreary waste; hence the larger herbivorous animals, under such conditions, will perish for the want of food, and the carnivorous will also have to migrate and perhaps suffer in a less congenial habitat: all become subservient to the various effects of geological mutations.

North temperate.—The tree-ferns and palms scarcely extend in a diminutive form to this zone. The small grass, fine meadows, and the periodical renovation of nature at the first genial opening of spring, become in this division of the earth more conspicuous than in any other. Although the gigantic forms do not flourish so far north, yet this part of the globe is more prolific in the variety of the lesser vegetable and animal productions. Some suppose that the long-haired elephantine animals, which are found imbedded in the northern sands, were once indigenous to this zone, and that animals of similar forms, belonging to the same type, were capable of living in the northern climates,—productions which are totally inconsistent to the physical conditions. Even were we to admit such a mode of reasoning, it could not be extended to vegetation, which requires moisture and tropical climate. No internal heat, in the absence of suitable external conditions, can produce gigantic plants with their delicate appendicular organs; therefore, as the one accompanies the other, the same mode of explanation is essential, and must be applied to both forms. We know from ample experience in hot-houses, that internal heat, in the absence of light and mild moist air, would be destructive to the glossy verdure of the vegetable kingdom. The heat of the volcanoes of Iceland would be of no avail to vegetable life in that latitude.

I have no doubt but that many parts of the lands of the northern hemisphere contain seeds of vegetable forms which cannot germinate for the want of the conditions the southern hemisphere still presents. To show that such instances occur, we need but refer to the fact, that in destroying large forests in South America, we frequently cause the growth of plants unknown to the inhabitants of the locality. Hence seeds may remain dormant or rendered as inactive as those found enclosed in the Egyptian mummies even in their congenial habitat, owing to the predominating powers of their more vigorous companions. In transplanting the northern plants to the south, they increase in magnitude, while those brought from the south to the north become dwarfish, and only the more hardy variety and the small species can conform to the transition.

The northern temperate zone is divided by the ocean into two great continents. The same tribes are found to be spread from the western to the eastern parts of the old continent; but the quadrupeds which inhabit the temperate climate of America are peculiar races analogous to its corresponding southern part;

whereas the former, owing to the sudden break from the tropics by means of the Mediterranean sea, presents a great range in the same parallels. In the arctic region, we find the White Bear, the Reindeer, Foxwolf, &c.

In proceeding from the torrid zone towards the arctic region, the animals become smaller, less numerous, and less ferocious. The reptiles and serpents gradually diminish in number and venom as we go north, until they disappear entirely in the frozen region. The smaller grass, grain and other nourishing farinaceous productions of this zone, although not sufficiently succulent to suit the larger animals of the preceding division, are favourable to the Horse, Ox, and other domesticated animals, and consequently these come to their perfection in this division. In the northern part of this zone the vegetation is very scanty, principally dwarfish oak trees, pines, and some evergreens; but the pasture is rich; rye, oats and barley can be cultivated almost to the boundary of the arctic region.

Before we close this chapter I shall make a few observations on the supposed predominance of carbonic acid in the atmosphere during the deposition of the coal-beds, inasmuch as the question has reference to the physiology of vegetation. The researches of M. A. Brongniart on fossil plants led him to conclude that during the early period, when the succulent plants entombed in the coal-measures flourished, the atmosphere was more charged with carbonic acid than at present, aiding, it is said, the development of the gigantic species seen in the coal; which were similar to those now living in the southern hemisphere. It is difficult to conceive how the idea of plants obtaining their carbon from the atmosphere originated, when it is a well-known fact to those who study nature, that the plants are fed from the *soil* by means of the absorbing power of the roots. The carbonaceous liquid enters the roots by their extremity, passes into the cellules, and reaches the stem, where the ascending movement is continued; it precipitates some portions of the component compound in its course, increases in density, and constitutes then what is called sap; and it feeds the woody fibre and the bark by means of the medullary rays.

The intensity of the ascent of the sap depends on the power of the bark, in the radial action, and the buds and the superficial area of the leaves in evolving the gases from the extremity of the pores of the fibres. The evaporation of the gases at the leaves keeps the ascending movement from cell to cell in activity, and this brings up the nourishment necessary for the development of the trunk. Those who have lived, like myself, for many years in the midst of such gigantic vegetation as above alluded to, are fully aware that the atmosphere (with the exception of being occasionally overcharged with moisture) is as pure as it is in the northern hemisphere.

The aborigines of New Zealand, Australia and South America, however ignorant they may appear to the world, would smile at the notions of our philosophers regarding the physiology of vegetation, and many other natural phænomena with which Europeans are not sufficiently acquainted. The evolution of the gases at the leaves has been found to vitiate the atmosphere, more especially at night, when the air is stagnant; the sun's rays appear to restore the purity of the air. I found by experiment that the elongation of the plants was greater by night than by day.

The soils of these regions are strongly saturated with carbonaceous matter, both elementary, and as deposits of pre-existing carbonaceous compounds; consequently with such an abundance of nourishment to feed upon, and *constant mild and moist* atmosphere to keep the leaves in a healthy active state to liberate the gases, the plants must flourish.

The function of the leaves is to evolve the gases, *i. e.* they form the negative plates as it were to the currents of sap in the vegetable battery. Had there not been a provision in nature to throw down the carbonic acid gas which occasionally contaminates the atmosphere, we could not exist; nor would vegetation thrive, as proved by experiments. Carbonic acid atmosphere, even to a moderate degree, is destructive to vegetable life; whereas, if absorbed by the soil, it becomes highly nutritious. Yet, although these facts are so easily proved, and well known to the cultivators of lands, we find the assumptions of carbonic atmosphere, and feeding by means of the leaves, encouraged by eminent scientific men.

CHAPTER XXIV.

ON THE APPARENT INFLUENCE OF THE MOON ON THE SURFACE OF THE EARTH, AS EVINCED BY THE ACTION OF THE TIDES AND THE SAP IN TREES, ETC.

THIS subject is not only very little understood in Europe, but almost neglected; with the exception of the movements of the tides, in which the moon is considered to be the prime mover, and made to act in a strange manner on the ocean (usually styled the theory of the tides), we have no other *acknowledged* records of her terrestrial operations amongst scientific men*. The abo-

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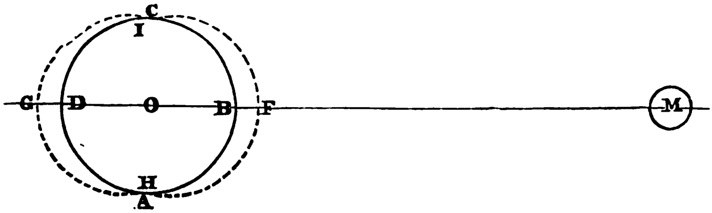
* It is said "that when any part of the surface of the sea is turned towards the moon the water is drawn towards it, and raised into a tide, which falls again when the place is turned away from the moon. The water rises to the same extent on the side opposite the moon; so that there is always high water on the two opposite sides of the globe at the same time. Let A B C D represent the earth, and M the moon, and let the surface at B next the moon, and that at D, opposite, consist of water." It is said, "as the force of attraction is greater in proportion to nearness, and less in proportion to distance, the moon will exert her greatest influence on the waters at B, which accordingly will be drawn towards the moon to F, and their surface will form the dotted curve. The waters on the opposite side being further from the moon than the earth, the moon will attract the latter more strongly than the waters. The earth, therefore, will be drawn away from these waters; and they *being left at a distance* somewhat greater than the usual surface, will appear to have risen from D to G." If the moon be capable of attracting the water at B, and the *whole bulk of the globe besides*, what keeps the water up at G? Surely the little covering at D would follow, if not withheld by some external power not noticed in the demonstration, and especially when the sun and moon are in conjunction. It may be argued that Laplace and other astronomers have



rigines of the torrid zone and southern hemisphere, where meteorological phænomena follow each other with great order and regularity, watch them with great attention, and their prognostics from the appearance of the moon are as much to be depended upon, or even more so, than the barometer in Europe.

Our knowledge of the general movement of the tides is so incomplete, that many believe that they are great meridional ridges, following the apparent movement of the moon, and not —as we observe them—waves propagated from the south. However, our object at present is not to enter into this question, but to show that there is an apparent physical connection between the moisture enveloping our globe and the moon. The tides move northerly in waves, and vary in their dimensions in both oceans with the changes of the moon: this is known from time immemorial; therefore we need not dwell on this effect, but proceed to the oscillations observed in the vegetable kingdom.

In carefully studying the action of the sap, more especially in the south temperate and torrid zone, we find that there is an intense ascending movement from the new moon to the full, and a repose during the decline. Indeed so regular and well-known is this fact amongst the natives of the hot countries, that it becomes a most important guide in cutting timber. They know from experience that if trees,—palms, bamboo, &c.,—be cut during the increase of the moon, they become rotten in a very short time, whereas if cut during the decline they are firm and permanent. I have made practical experiments for upwards of nine years, and have proved the above to be a fact, and if the rule for cutting be neglected no woodwork of any permanent value could be made. So strongly saturated are the trees during these periods,

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established the consistency of such a doctrine: but as all the complicated and intricate analysis used rests on the truth of the conjectures or assumptions made for procuring the possible application of the fundamental equations, the argument is of little avail. Had such tides existed at the equator, proportionably to the supposed attractive curve, in the ratio of the length of the ordinates, according to the geometrical degrees of intensity, the Low Countries would be completely inundated; but the fact is, there are *no such tides at the equator*, in the Atlantic, nor in the Pacific. The tides bordering the Pacific islands and in the West Indies are comparatively insignificant, amounting only to a few feet, and the movements of which are totally different to that indicated by the above theory, as already explained, and well known to mariners.

throughout the year, that if cut down they become immediately affected by the dry rot. During the latter period of the change, the gases evolved from the leaves and the woody substance become consolidated, and they are rendered fit for cutting. The rings of the trunks are formed monthly in the southern hemisphere, by the expansion of the outer part during each period of activity: hence a tree of twenty years frequently contains 260 rings called 'annual rings' by Europeans, the fossils of which lead to erroneous computations.

In crossing the Andes, we find it much more convenient to travel through places where there is a deficiency of water, during the increase of the moon than the decrease, inasmuch as we are able to obtain pure water by tapping the trees in the former case, but not on the decline. The action of the sap accompanying the changes of the moon is equally conspicuous in the operation of cutting and grafting, which if not attended to will endanger the life of the plants. Nor is this apparent influence of the moon confined to the southern hemisphere and torrid zone, but also extends northward. They know in the United States that it is essential to the durability of timber to cut it at the period of the 'dark moon.'

This fact has been found of sufficient importance in the United States to cause the government to establish the following law; viz. the timber supplied for the navy ships of war is required to be girdled, or felled at the *dark moon*, between the 20th of October and 12th of February. White pine logs, if stripped of their bark and cut at the proper period, *i. e.* during the decline of the moon, will remain uninjured thirty years; whereas if cut at the increase of the moon, they will be either attacked by worms, or destroyed by dry rot in a very short time. These effects are much more conspicuous in the south than they are in the north, but nevertheless they are of great practical importance in all countries where timber is required.

It is interesting to study these also in the animal kingdom: they are as striking and unequivocal as in the former; and are sufficient to prove the connection that exists between the surface and the moon, although the mode of operating is very different to that explained in our old theoretical works.

CHAPTER XXV.

ON THE GENERAL NATURE OF THE DISTRIBUTION OF HEAT OVER THE SURFACE OF THE GLOBE, AND THE ZONES OF EQUAL TEMPERATURE.

It is now well ascertained that zones of equal warmth, both in the atmosphere and in the waters of the ocean, are neither parallel to the equator nor to each other. It is also known that the *mean* annual temperature may be the same in two places which enjoy very different climates; for the seasons may be nearly uniform or violently contrasted, so that the lines of equal winter temperature do not coincide with those of equal annual heat. The deviations of all these lines from the same parallel of latitude are determined by the position, direction and elevation of the continents and islands, the position and depths of the sea, and the direction of currents and of winds.

The amount of the solar heat depends upon the position of the sun, the direction in which the sun's rays strike the earth, and the variable degrees of intensity occasioned by the atmospheric lens, illustrated in Plate III. In proceeding from the equator towards either of the poles, without altering our height above the level of the sea, we must travel a great distance before we find the mean annual temperature reduced even a few degrees; but by increasing our elevation, a rapid change of temperature will be experienced, till we arrive at the point where constant frost prevails, *i. e.* the curve of congelation. (See Plate III.) The annexed table shows the relative height of this curve in different latitudes from the level of the sea:—

Latitude.	Height of Curve of Congelation.	Mean temperature at the level of the sea.
0	16,000	84·2 Fahr.
10	15,600	82·6
20	14,500	78·1
30	12,600	71·1
40	10,000	62·6
50	6,900	53·6
60	3,900	45·0
70	1,000	38·1
80	0	32·0

The variable temperature of the sub-aërial zones in the ascending order is also observed in the sub-aqueous zones from the level of the sea downwards. At the equator, commencing from the level of the sea upwards, we have the following:—

	Mean temperature.		
Level of the sea	84°.		
4,000 feet high	70°,	descending to the level of the sea in	30° N. lat.
8,000 ,,	62	,, ,, ,, ,,	40
12,000 ,,	44	,, ,, ,, ,,	60
16,000 ,,	32	,, ,, ,, ,,	80

These curves descend more rapidly in the south than they do in the north.

From the level of the sea downwards the temperature decreases in the torrid zone from 82° to 39°: the sub-aqueous zones are not so uniform as the aërial, and are considerably influenced by the polar stream.

According to the concentrated rays, the heat of the sun ought to increase in depth, and such would be the case in an empty space; but liquids conduct heat very imperfectly downwards. A thermometer let down a few feet below the surface of a pond or of the sea, would, on being drawn up, indicate a lower temperature than that of the surface; for the latter, heated by the rays of the sun, would communicate by conduction little or no heat below. It can be proved by experiment, that water does not transmit heat downwards by conduction; whereas, in applying heat underneath it is easily transmitted. Had the globe contained an igneous nucleus, whatever might be the bad conducting quality of the crystalline shell, it would be heated, and that heat would be communicated to the ocean, and an ebullition would be produced sufficiently strong, if not to cause evaporation of the ocean, at least to prevent the formation of ice at the poles, and the heat would increase as we descended. The observed facts are quite the reverse. The ocean at a certain depth possesses a constant temperature of about 39° below the influence of the heat of the tropics or the cold of the north; it is at the surface the greatest variations of temperature take place, and from which they diminish as we ascend into the air or descend into the ocean, till in each direction they terminate at an invariable temperature, where the solar radiant heat becomes insensible; and it is within these zones of variable temperature that the animal and vegetable kingdoms are bounded.

According to the above, we find that in sailing from the south pole to the north we are exposed to zones of variable temperature, commencing at 32° Fahr.; and on arriving at the equator, it amounts to 84°·2, and becomes reduced again as we approach the north pole to 32°. If, instead of sailing on the ocean, we sail through the air at the elevation of the above curve, we should be constantly exposed to the low temperature of 32°. The variable height of the land between the level of the sea and the curve of congelation must therefore vary the climate of the different zones, independent of their latitudes. Within the tropics we may obtain any temperature from 84°·2 to 32°, by regulating our elevation; but in the frigid zone we are limited for the want of direct rays, and cannot obtain a mean temperature above 50° by depression, or by any other means we may choose to adopt; consequently no changes in the relative position of land and sea can produce a tropical climate in the polar zone. Countries in the northern hemisphere are rendered warmer by having large tracts of low land to the south and sea to the north, and cooler when the relative positions of these two are reversed. This fact is exemplified by a comparison of the climate of Europe with that of America and Asia. The western parts of the old continent derive considerable warmth from the low sandy region of Africa and the Gulf-stream. On the contrary, the north-eastern extremity of Asia and the west coast of North America experience in the same latitude extreme cold; for they have land on the north between the sixtieth and seventieth parallel, and to the south the Pacific Ocean. The whole of Europe, compared with the eastern parts of America and Asia, has a much warmer climate than is due to it according to its geographical position. If lines be drawn round the globe through all those places which have the same winter temperature, they are found to deviate from the terrestrial parallels much more than the lines of equal mean temperature. All these important considerations must be well borne in mind when we enter into the boundaries of the respective zones.

Having thus noticed the subject of temperature, it will be proper to advert to the amount of moisture which the atmosphere contains in different parts of the globe. We have already alluded to the character of the southern regions, and that the evolution of hydrogen was probably the cause of the excessive moist atmosphere and the mildness of the climate. In the temperate zone of the north, with a mean temperature of 52¼°, the annual evaporation has been found to be between thirty-six and thirty-seven inches. At Cumana, on the coast of South America (north lat. 10½°), with a mean temperature of 81·86 degrees, it is more than 100 inches in the course of the year; at Guadaloupe, in the West Indies, it has been observed to amount to ninety-seven inches. The average yearly quantity of rain is greatest within the tropics, and it seems to diminish the further we recede northward from the equator. In general much more rain falls in mountainous countries covered with extensive forests than in those where wood is less abundant, owing probably to the excessive evolution of hydrogen. The following table shows the quantity of rain fallen at Marmato, on the western Cordillera, latitude 6° 28′ north, elevation above the level of the sea 4836 feet, mean temperature about 68°, from the year 1833 to 1841 inclusive, registered principally by the author.

	1833.	1834.	1835.	1836.	1837.
	Ins.	Ins.	Ins.	Ins.	Ins.
Jan. to March..	15·15	5·15	25·14	23·3	8·1
April to June..	24·3	29·6	34·6	39·4	23·9
July to Sept. ..	2·0	12·9	21·2	18·3	18·1
Oct. to Dec. ..	17·8	24·12	36·14	28·10	31·16
	59·6	72·2	127·16	99·0	81·7

	1838.	1839.	1840.	1841.
	Ins.	Ins.	Ins.	Ins.
Jan. to March..	21·10	10·16	18·3	12·3
April to June..	41·18	28·0	22·0	26·2
July to Sept. ..	19·0	23·16	9·3	16·35
Oct. to Dec. ..	31·0	31·18	14·17	32·2
	113·8	94·10	64·3	87·2

It must not, however, be imagined that the climate of all hot countries is characterized by such abundant rains; for there are many parts which from one year to another are either almost or entirely destitute of rain. This is the case along an extent of several hundred miles on the coast of Peru; yet the atmosphere is highly charged with moisture. There are other places on the shores of that continent where but little rain falls, but where, nevertheless, vegetation is exceedingly luxuriant, owing to the humidity of the atmosphere.

In the torrid zone, generally, the temperature ranges within comparatively small limits, and the various phænomena of the atmosphere, as observed by the barometer, occur from one year to another in a regular and uniform succession unknown in Europe: the *dry* and *rainy* seasons are the divisions of the year, depending on the position of the sun and elevation of the lands.

The subject of climate is in itself highly interesting; but it becomes still more so when we extend our view, and consider its effects upon the numerous animal and vegetable tribes which are dispersed over the earth, and compare them with those of the past, which are now entombed in our rocks.

Every climate, as we pass from the plains just raised above the level of the ocean to the curve of congelation, has its peculiar vegetation. At the equator palms flourish within the zone, varying from 80° to 60° of mean annual temperature; but on ascending to the elevation of 8000 feet above the level of the sea, to a mean temperature below 60°, they almost cease to grow. On ascending above the elevation of 8000 feet at the equator, the arborescent ferns cease to grow, and in the next zone (above) the vegetable tribe of the hot region disappears, and new varieties make their appearance, such as the oak, firs, and several others common in the temperate zone of the north. Near the equator the oak grows at an elevation of 9200 feet above the level of the sea, and never descends lower than 5500 feet. It therefore follows that if the whole of the land within the tropics were to be elevated to 8000 feet, all the tropical plants would disappear, as there would be only a temperate zone within the tropics, and even the larger animals would perish for the want of the necessary food on the flanks; if, on the contrary, the land was depressed so as to be entirely below 3000 feet, or say mean temperature 75°, there would be only the productions of the hot regions, and consequently a predominance of the large class of reptiles and other tropical animals and plants, with the bordering sea corresponding: therefore the oscillations of the land must considerably influence the width and parallelism of the organic zones. In the former there would be no tropical band on dry land, and in the latter case it would be much augmented; consequently they can never be definitely marked, or permanently preserve their parallelism.

Each description of zoophyte has its place of residence determined by the temperature and nourishment required for its support, not alone from the sea, but also from neighbouring continents. The zones of depth below the level of the sea are governed by a similar law, but inversely to that above.

If we take a general view of the zones of equal temperature, both above and below the level of the sea, and consider that each has its peculiar vegetation, and again, that each zone is furnished with different groups of animals adapted to its temperature and general production, we can easily conceive that a very slight oscillation of land and sea would cause the extinction of whole genera of animals and plants, and that those bands of variable temperature, from the equator to the poles, can never be expected to be parallel to the equator, but always to present great undulations according to the relative position and height of the dry land and the bottom of the sea. The conditions of the Pacific Ocean are also different to those of the Atlantic. Therefore, in tracing the general effects of the northerly movement of the surfaces, and comparing the effects with existing nature, we must take all the above questions on the modifying causes of temperature and variable distribution of vegetables and animals into consideration, and not be limited to the mathematical zones of geography.

CHAPTER XXVI.

THE DIVISION OF THE SURFACE OF THE GLOBE INTO ZONES OF DEPOSITION.

Having explained the northerly movement and the general character of the surface, we are prepared to examine the respective deposits, and study them in their progress from the south towards the north; and distinguish their zones of deposition in the following order in accordance to the character of their contents:—

	Zones.	Deposits.
No. 1.	South frigid	The most ancient sedimentary rocks, Cambrian and Silurian.
No. 2.	South temperate	The Carboniferous, or the great coal formation.
No. 3.	South tropic	Oolitic or Saurian group.
No. 4.	North tropic	Cretaceous and tertiary of Europe.
No. 5.	North temperate	Alluvial deposits of Europe.

1. *South frigid.*

We have already shown that this region is a barren waste, consequently the deposits can only contain marine shells, and towards the outer margin some marine plants; and it is a singular fact, that the shells correspond more or less to those found in the ancient rocks. The fossils obtained by Mr. Darwin from recent formations of Tierra del Fuego and Falkland Islands, can hardly be distinguished from species found in the Silurian rocks of England.

In Victoria Land and Franklin Islands, which are now rising from the deep, preparing new continents for future generations, there are no traces of vegetation nor terrestrial animals; hence the deposits can only enclose marine relics, and those only that inhabit that region.

2. *South temperate deposits, or the Zone in which the great Carboniferons formations were deposited.*

The forms of life buried in this system of strata are exceedingly numerous and varied, and generally in an excellent state of preservation, allowing of a most strict comparison with existing types. They consist of many races of plants, abundance of Zoophyta, with multitudes of Mollusca, Crustacea and Fishes. The plants are similar to those which still flourish in the zone, such as the large group of ferns also, the Equiseta, Lycopodiaceæ, Araucaria, Cycadeæ, Coniferæ, &c. The remains of these plants are often abundant in the coal formation. The coal plants of Europe and America are for the most part identical, and all belong to the same genera. Specimens from Greenland are referrible to ferns, analogous to those of our European coal mines. The fossil plants brought from Melville Island warrant similar conclusions, that they were all deposited in the southern hemisphere. The coal formation at Bogota, which is situated within 4° north of the equator, at an elevation of about 8000 feet above the level of the sea, contains the same kind of plants—arborescent ferns, and Lycopodiaceæ of the same species as those now growing in the southern hemisphere. The living representatives of the above are still found in Australia, New Zealand, Brazils, Chili, and various islands within the south temperate zone. Not a single species of Cycadeæ is known to grow in the north temperate region; their principal localities are equinoctial America, and southward of that part,—the Cape of Good Hope, Madagascar, India, the Molucca Islands and Australia.

The enlarged size of the arborescent ferns depends not only on a warm temperature, but also on a shady and moist place. Within the tropics they are found at an elevation of about 8000 feet above the sea, near the plains of Bogota, from twenty to thirty feet high, flourishing only in shady parts of great humidity. It is in the south temperate zone of America that the ferns and palms approach to the magnitude of those found in our great coal formation. Trees still grow in this region to a very large size, and the shrubs and smaller plants become particularly luxuriant and very productive. Much alluvial matter, saturated with calcareous and siliceous solutions, is carried down the valleys, blended with decomposed vegetation, and forming immense deposits. Springs of bitumen are also very abundant, and forming very extensive beds.

Were persons a little more acquainted with this prolific region, and possessing more information respecting the great deposits of calcareous, siliceous, bituminous beds, &c. which are now forming in this part of the world, they would not encourage the assumptions that the contents of the deposits represented the character of the terrestrial fauna; they would learn that they are necessarily exclusively marine. The placoid fish found in this formation, which Agassiz refers to the Cestraciont sharks, are a family still existing in the Australian seas.

This zone, as already described, contains abundance and variety of the Cycadcæ, Araucariæ, &c. on land; and Terebratulæ, Trigoniæ, Cestraciont fishes are swarming in the seas that wash their shores, corresponding to the ancient lands and seas when and where our coal formations were deposited. Those who encourage the notion of successive creations from not finding the rocks containing all the variety of organic beings, and because the consolidated sediments predominate in shells, fishes, &c., would receive a useful lesson in these regions.

Australia is exceedingly deficient in Saurians and other terrestrial quadrupeds. Hence the contents of the carboniferous group, even were land animals equally susceptible of being carried and preserved in deposits, accord well with the apparent prevalence of such a state of things in the southern hemisphere during their respective depositions.

We cannot expect to find any large coal formation far south of the tropics, but mere bituminous seams mixed with sands and clay; because should there be any forming it would be below the level of the sea, and not yet sufficiently consolidated to make good compact crystalline coal. The genuine coal formation cannot make its appearance of any magnitude until we come to the margin of the south tropic. The so-called coal formation of Australia, in 33° south latitude, is enclosed in beds of conglomerate and sandstone, with subordinate beds of bituminous shale, and very different in character to the coal formation of the north.

The dry lands of the south temperate zone are necessarily void of the sedimentary rocks. They are principally composed of the primary series, with sands and clays partially consolidated; those now emerging from the ocean in that region have not been exposed long enough to the conditions required to form the great coal formation.

Our coal-beds are as much due to the combination of carbonic acid and hydrogen forming bitumen, as they are to decomposed vegetation. We have abundant facts to prove that plants are more liable to become silicified than to be converted into coal.

There are immense accumulations of fossil trees seen in Tropical America, all of which are indigenous to that zone. It is very interesting to observe, that in all cases the change in the organic substances depends entirely on the nature of the local solutions, and the matter in which they are enclosed, and not on the nature of the trees. It does not follow that plants should be converted into coal by being entombed in sedimentary beds of clay and sand.

Should the accumulated deposits become charged with siliceous solutions, the organic remains which may be enclosed will be silicified, be they plants or animals; and if the solutions be calcareous, they will be converted into calcareous fossils; but a large proportion of the more delicate parts become destroyed and obliterated during the chemical changes. It is only where we see bituminous springs in swamps, and lagoons containing beds of decayed palms and succulent plants, that anything approaching the conditions required to produce the coal formations is observed. Massive trees are seldom found converted into coal, even when found in the coal formation; whereas we do find thin seams of crystalline coal without the least trace of decomposed plants. The seams of decomposed vegetation are extremely irregular, whereas coal seams are the most uniform seams in the series, and which could only be produced by a semifluid substance analogous in consistence to bitumen or native pitch. The impressions of plants are generally found in the shale covering the coal, as if they floated on it, and are rarely seen *in* the coal itself.

Stumps or roots are frequently found in the fireclay under the coal; and sometimes trees intersect the seams vertically from the clay, through the coal, shale, &c., without being converted into coal, but, on the contrary, changed into indurated clay.

The compressed wood on the brown coal formation, seen in various places on the continent, is very different to the true mineral coal, and may be very properly called lignite. They are beds of wood preserved from decay, and from mineral elements, analogous to the great trunks of trees found in bogs, which, although compact and black, are far from being coal. The cause of the supposed resemblance arises from the similarity of their *composition*, both being a compound of carbon, bitumen, &c.

Thin veins of anthracite have been seen in the superficial joints of granite and porphyry; plumbago has been found in granite and schistose rocks; in fact, bitumen flows from porphyries and schistose rocks in North America. The Lake of Trinidad is formed by such springs.

The numerous small veins of coal found in limestones, sandstones, clayslates, &c. intersecting the beds like quartz veins, prove most distinctly that they were formed by carbonaceous matter in solution and crystallized during consolidation*.

3. *South Tropical Zone. The system of rocks between the carboniferous strata and the chalk, containing a large proportion of gigantic amphibious Saurians.*

The oolitic group may be considered as representing this division of the series. The remains of plants, Zoophyta, Mollusca, Articulosa, and vertebral animals belonging to the oolitic system, are very numerous. The most characteristic of the plants are the group of Cycadeæ, of which stems in the isle of Portland, and leaves and fruit in Yorkshire, show considerable analogy to the existing forms of the tribe at the Cape of Good Hope, in India and Australia.

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* There is a very erroneous notion prevalent respecting the diamond. It is commonly considered as mere crystallized *charcoal* or *coke*. These comparisons necessarily lead to incorrect ideas respecting the origin of this crystalline gem. It is a pure crystal derived from the original element of carbon, like all other crystals. We may as well call a crystalline phosphate of lime, bone, or carbonate of lime, shell, as to call a diamond charcoal. The diamonds are only found in the debris of the primary crystalline rocks, like garnets, and consequently formed in the primary base from the original elements, and not by means of the transformation through the medium of vegetation, as the comparison leads the masses to infer.

The sponges resemble those of Australia. Among the Saurians, those which frequented the water necessarily predominate in number, but the largest forms were terrestrial (Iguanodon, Megalosaurus), but apparently deposited in local inland basins under favourable conditions for their preservation. We observe that the earliest Mammalia, of which we have yet any trace, were of the marsupial division commonly seen in South America and now almost characteristic of Australia, the country where yet remain the Trigonia, Cerithium, Isocardia, Zamia, tree-fern, and other forms of life so analogous to those of the oolitic periods. During the deposition of the European formation the rivers and shores were inhabited by Saurians more or less amphibious, while the sea was full of forms of Zoophyta, Mollusca, Articulosa and Fishes.

Within the south tropical zone we have a reflected image, as it were, of the organic contents of this division of the series in the seas and lagoons of South America. Here the rivers, such as the Amazon and its shores, are watched by amphibious Saurians, the living representatives of the Megalosaurus and Iguanodon. Although the identical species have become extinct, yet the alligator, crocodile, gavial, and the bavial of South America (the latter was seen by the writer in the lagoons of equatorial America, having a head like an iguana and a body like a crocodile), are sufficient to show the correspondence of this zone to the fossils of the oolitic group. The Galapagos Islands swarm with herbivorous, marine and terrestrial reptiles, allied to the Iguanidæ, which are unknown in other zones.

When we consider the myriads of reptiles which inhabit this zone, it is not surprising that their relics should be found occasionally in sediments deposited within their own element; but it would be extraordinary indeed to find traces of man and his works in such deposits. There are regions at present in the Indian and Pacific Oceans co-extensive in area with the continents of Europe and North America, where we might dredge the bottom and draw up thousands of shells and corals without obtaining one bone of a land quadruped. The dredgings bordering our coast have only produced marine relics; no terrestrial remains have been found; therefore were we to reason from such evidences on the probable state of organic life, we should conclude that there were no reptiles, birds or quadrupeds existing in the neighbouring land. The casualties must always be rare by which land quadrupeds are swept by rivers far out into the open sea, and still rarer the contingency of such floating bodies not being devoured by sharks or other predaceous fish. If the carcass of a terrestrial animal should escape and happen to sink where deposits were accumulating, and if the numerous causes of subsequent disintegration should not efface all traces of the body, is it not contrary to all calculation of chances that we should hit upon the exact spot? Can we expect for a moment, when we have only succeeded amidst several thousand fragments of corals and shells in finding a few bones of even aquatic or amphibious animals, that we should easily meet with land animals? Are we then warranted in supposing that man was not an inhabitant of this world during the deposition of the oolitic group, not alone in the south tropical regions, but in the northern hemisphere? In the first place, the southern hemisphere is but thinly inhabited; and if perchance a man be carried into the rivers, he would soon be devoured amongst such a profusion of carnivorous reptiles. As to the works of man within this zone, even at the present advanced state of civilization, they consist of such materials that their remains would be undistinguishable from the wrecks of the forest. Therefore we have no reason to assume that man was not an inhabitant of this world during the deposition of the series in question, and much less other terrestrial animals.

Let us take as an example the banks and lagoons of the Amazon, which are swarming with reptiles, and consider the nature of the deposits forming at the mouth of this immense river. The inhabitants of the country are principally roving Indians, living in bamboo huts; probably we should not be far wrong in stating, that for every man there are within this region 100,000 amphibious reptiles. Again, for every man, or quadruped, which may be carried into the mud of the river and escape being devoured, there will be deposited myriads of amphibious reptiles. The large aquatic birds of South America are never found in deposits, yet we find their foot-prints on the sand-banks of the lagoons and rivers. I have looked in vain, during my researches in South America, for terrestrial organic remains of animals in the deposits now forming, whilst the freshwater and marine relics were often very abundant.

Some of the oolitic beds of Europe seem composed of little else than the remains of shells and corals, like the deposits now forming in the Pacific. A very striking zoological feature of this formation is the immense abundance of Ammonites and Belemnites, which must have existed during the deposition of the European group, and also when the most recent equivalent of the same division was formed, as now seen near the equator*.

It would far exceed our limits to enter into the general comparison which might be made, even to minute details, of the living representatives and the depositions of the river Amazon, and other parts within the south tropical zone, with the fossils and deposits of the oolitic group of the northern hemisphere; and as it only forms but a mere link in the chain of argument in support of the northward movement of the surface, we must content ourselves with a general glance. As this system of deposits was formed within the south tropical zone, the corresponding sedimentary beds, already emerged at the equator, are superficial, and in a very unconsolidated state as compared with those seen in the north. The equivalent of the European oolitic group in equinoctial America, from the Amazon to the Orinoco, and on the plains and table-lands of New Grenada, is an immense mass of alternate beds of fine-grained quartzose sandstone and conglomerates, containing Ammonites, Belemnites, and a variety of other marine shells, together with species of fossil plants of the Cycadeæ, Coniferæ, &c.; and on the superficial, arenaceous and unconsolidated part of the same series are found immense bones of the Mastodon. These bones are very abundant in the province of Nieva, amongst which are the remains of the alligator, and other existing types.

In New Grenada this series of sandstone is stratified in layers more or less horizontal; a great number of the thinner and upper seams are composed of decayed leaves and impressions of plants the same as those now growing on the spot. On the plains of Mariquita and Nieva are immense isolated terraces presenting beautiful sections of 2000 feet high; and also on the plains of Bogota, resting on the coal formation of that district; whilst on the west this formation rests immediately on the crystalline schists of the central Cordillera*. The elevation of this part of South America from the level of the sea (which appears to have been comparatively recent) must have been extremely uniform in this region. There are but few beds of the oolitic group sufficiently consolidated for building stones, and those that are so employed are much softer than the common freestone. Stems of succulent plants are commonly found, as black as jet, in the harder beds.

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* Some of these Ammonites, which were brought from the equator and presented to the Geological Society by the Author, are figured and described in the Geological Proceedings, vol. iv. No. 101.

In examining recent deposits within the tropics, we often find the accumulations of only one variety of plants; and it is remarkable that some of those which are common in the neighbourhood are yet absent in the deposits. Some plants appear more susceptible to rapid decay than others; hence it follows that a series of beds may be found to contain only a particular class of plants, without a trace of many growing within the district. We note these facts in order to guard against the too hasty conclusions of supposing that the fossils always represent the general character of the whole variety of vegetation, much less the animal kingdom.

4. *North Tropical Zone.—The Cretaceous and the so-called Tertiary Deposits of the Northern Hemisphere.*

Although the English sedimentary rocks are divided into distinct groups, it is not a natural and definite subdivision, but depending entirely on local circumstances, and very far from being applicable in the same parallels, much less in more southern latitudes. A perfect transition from one formation into another is of more common occurrence in nature than distinct separation. Besides, instead of being piled on each other as represented in the common geological sections, they merely lap over at their respective margins. We have no cretaceous equivalent to the European in the equatorial zone. The remains of crocodiles have been found in the chalk of Meudon, and the exuviæ of large reptiles at Maestricht. The remains of fish are abundant.

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* See Section of the Andes.

In examining the corresponding deposits which are now forming within the tropical region, we often find a great number of beds containing only marine and freshwater organic remains, and it is but in very few instances that we can detect traces of terrestrial animals. In some parts, large deposits of carbonate of lime are seen, with scarcely any organic remains, although forming at the same time as those deposits in which they are very abundant. Those persons who confide in what are hastily called general views, and believe in the gradual change and sequence of organic life on the globe, and picture to themselves the early land and sea as tenanted only by what they find in the sedimentary deposits of a particular region, from what they consider simple forms of life to a more complicated, till man, as they say, was at last awakened to the supremacy of creation,—would receive a useful lesson on the banks of the river Magdalena and the lagoons of Santa Martha; they would soon perceive that the few fossil birds and quadrupeds of Stonesfield, and other places, are not anomalies so puzzling as they were once considered.

Although there have been actually found, not only the bones of quadrupeds, and various terrestrial animals, but also those of man, amongst the remains of the extinct animals, in caves, &c., and also in a fossil state in the calcareous deposits of Guadaloupe, yet so obstinate is the adherence to the supposed recent origin of man and the living system, as compared with the organic remains of the sedimentary rocks, that such discoveries are not considered sufficient to prove their coexistence. Various species of monkeys have been found under similar circumstances, which were at one time considered of the same recent origin: this must show the inconsistency of the hypothesis, and how untenable doctrines check the march of scientific truths.

In the red sandstone, which occupies nearly the same geological position as the cretaceous group, in Dumfriesshire in Scotland, and Massachusetts in North America, we find the impressions of the feet of birds, and the foot-marks of tortoises. On the banks of the river Magdalena, between Mompox and Morales, the writer saw impressions of foot-marks similar to those of birds of a most gigantic size,—feet measuring about fourteen inches long and eight inches wide, having three claws, and the steps four feet; amongst which were also those of tortoises, and various other animals well known on the banks of the river. So dissimilar were the impressions to any other but birds, as not to leave a doubt at that time but that they were produced by them, and those who have seen the drawing of these trifid foot-marks came to the same conclusion.

During a subsequent visit to this region I was determined to make a further examination of these impressions, and I found that those bird-like foot-marks were produced by the Dante!—thus showing how easily we may be misled from the impressions of existing nature, much more in the imperfect impressions of the past*.

The trees in the *dirt-bed* in the neighbourhood of Weymouth stand in or rest upon the soil in which they grew; consequently their submersion beneath the water in which the Purbeck beds were formed, and which now cover them, must have been gradual and unaccompanied by a rush of waters. Such is the case in the present formation of their equivalent in the lagoons of Santa Martha, where the trees are growing in shallow water, subject to slight oscillations above and below the level of the sea. Sometimes the salt water prevails, and the sediment becomes thickly covered with marine shells: during the great floods pouring down the Magdalena, carrying with it immense forests and the debris of rocks, the lagoons become again covered with freshwater and terrestrial organic remains. Thus, by variable seasons, and by the slow oscillation of the land by subterranean forces acting for a long period, the variable sedimentary beds are formed, such as we now see them when exposed to view.

Professor E. Forbes, in his excellent observations on the Mollusca and Radiata of the Ægean Sea, states, "It was found to be a law, that the extent of the range of a species in depth is correspondent with the extent of its geographical distribution. On the other hand, species having a very limited range in depth were found to be either peculiar Mediterranean forms, or such as are extremely rare in the Ægean, but abundant in more northern seas. The Testacea of the Ægean are for the most part dwarfs, as compared with their analogues in the (southern) ocean, and the number of Medusæ and Zoophytes are comparatively small. Below the fourth region in depth the number of animals diminishes as we descend, until, in the lowest part of the eighth region, the number of Testacea was found to be only eight, indicating a zero in the distribution of animal life at probably about 300 fathoms.

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* I have no doubt but that the trifid impressions in the Red Sandstone of Connecticut, were produced by similar animals, and not by birds, as I have carefully compared them both.

"In the upper regions the more southern forms prevailed, whilst those of the lower zones presented a northern character (corresponding to the temperature of that region), indicating a probable law, that in the distribution of marine animals regions of depth are equivalent to parallels of latitude.

"Any oscillations of level, however slight, would produce alternations of strata containing distinct groups of organic beings with others void of such; and partial alternations of marine and freshwater beds would be formed, a phænomenon now in progress on the coasts of Asia Minor. All this would occur without convulsions or violent catastrophes of any kind. Changes of level, however slight, might cause the extinction of whole genera of animals and plants, of which only such as hard parts would be preserved. Were the present sea-bottom of the Ægean to be upheaved, whole classes of animals would disappear and leave not a trace behind to assure the future geologist of their having existed."

We find these periodical oscillations of level going on in the Caspian Sea; these, together with the shifting of the position of its waters, partly by the encroachments of deltas on one side and the overflowing of the land on the other, cause some buildings to depress under water, while others are seen risen to a higher elevation; yet these changes are going on as quietly and imperceptibly to ordinary observation as those which must have affected the temple of Serapis.

Lacustrine deposits of the same period may present very different characters, depending on the nature of the locality in which they may be formed: for instance, the lagoons of the Orinoco may contain a very different series of organic remains, as compared with those of the Magdalena; hence formations may be of the same age and the same zone, yot different in degrees of induration and organic contents, as well as in their relative geological position. Immense rivers may disembogue themselves into an inland sea, like the Mediterranean, one coming from the south and the other from the north, and thus cause an apparent anomaly in the contents of the deposits. Viewed generally over a considerable area, the rock called chalk is based either upon an arenaceous or argillaceous deposit. As we cannot expect uniformity in the distribution of detritus, unless under conditions which could scarcely ever obtain, we should anticipate that sands would predominate over one part of the area and mud or silt over another, as we now find to be the case in the present deposits forming within the tropics. Some of the white variety may probably have resulted from the precipitation of carbonate of lime from solution in water, in favourable localities, suitable for the reception of calcareous springs.

The supracretaceous group of Europe completes the great sedimentary system of rocks; during the deposition of which it has been supposed man, with the present organic system, came into existence, simply because the remains are principally found in the superficial part of the series, not as fossils, but their bones, a state of things very common to superficial entombments. Some of the larger animals are completely preserved in the ice of the north. These superficial and partially consolidated sediments of sand and mud constitute a large proportion of the dry land of Europe; and there are abundant evidences that they are, comparatively speaking, of recent origin, and that a great portion of the dry lands of the north have been submerged and raised from the sea since they were exposed to a hotter climate. The chalk of the north, the oolite of the tropics, and the coal formation of the south temperate, may be all of the same age; hence it will be observed that the present mode of distinguishing these rocks is only applicable in certain localities, in the same parallels of latitude.

Sir H. De la Beche very justly remarks that "classifications entirely founded on organic remains are at all times liable to be erroneous, if contemporaneous deposition be thence inferred as a necessary consequence, as we have had occasion to observe; they therefore may be considered as doubly liable to error when employed in proving contemporaneous origin in such rocks as those of the supracretaceous period."

Palms and crocodiles are found in these deposits, analogous if not identical to those now found in Africa and in the neighbourhood of the Nile. That a great number of organic beings should have become extinct during such great oscillations of the earth's surface is a natural consequence; it is surprising that so many of the grand stock should have been preserved amongst the numberless vicissitudes of climates, and the separation of continents into islands, and *vice versâ*.

The last group of sedimentary beds pass so insensibly into the superficial alluvial deposits that no line of demarcation can be definitely drawn; we shall therefore close this subject by observing, that the alluvial and loose accumulation of sands, &c. covering the surface of the northern hemisphere, contain principally organic remains belonging, or indigenous, to the south part of the zone in which they are now found. The northern parts of Europe, Asia and America, contain large accumulations of terrestrial animals belonging to more southern climates. This division of the globe is rich in terrestrial relics to the confines of the Arctic seas, all proving the progressive advancement of the lands northward, while the living system gradually retrogrades southward. Hence the cause of the natural conclusion that the northern lands are getting colder, and that the world is consequently populated by Northmen. As the organic contents of the sedimentary rocks are so well described in almost all geological works, we must beg reference to them, trusting that the outline we have given here is sufficient to show the agreement in the order of the sedimentary rocks with the action of the northerly movement of the magnetic force, and that this prime mover, which controls our planet, is equally available to guide us in our researches in sedimentary rocks, as it is in the fundamental series and mineral deposits.

CHAPTER XXVII.

GENERAL RECAPITULATION OF THE ELECTRO-MAGNETIC EFFECTS.

If we now take a general view of the effects of terrestrial magnetism in combination with other secondary agencies really existing, we find sufficient natural causes to explain all the changes which have been observed in the earth's condition, in the degree, combination and sequence which actually belong to them. Each of the phænomena, taken singly, is capable of demonstration in all its details of circumstances by the operations of this great power in connexion with the existing elements.

First.—We have ample proofs of the existence of the magnetic fluid enveloping our globe, and that it affects the condition of the atmosphere; it has two points of convergence, which we call poles; that this fluid has a motion from the south to the north pole, and has an influence on all matter, causing all bodies to be drawn towards the earth, which we call attraction of gravitation, and also tends to cause bodies to arrange themselves in a meridional direction, called polarity, as shown by the magnetic needle; and that the latter action tends to propel all matter northward; and finally, that it acts both mechanically and chemically over the entire surface. We have abundant evidences of the mighty influence of this power over every part of the surface of the earth; the land, ocean, and the air, are all pervaded by it. We find it in the thunder-storm, earthquake and volcano, in the minute molecular actions of chemistry and processes of the living organization. We might expatiate on its apparent influence on a yet mightier scale in the movements and form of the planetary bodies surrounding us in space.

Secondly.—The northerly movement is observed in the ocean, which is found to carry all substances that happen to fall in it from the south to the northern regions. This northerly movement of the elements, and more especially the surrounding ocean, is strongly marked in the configuration of the dry lands. The great continents and many of the islands are more or less pointed towards the south, *i. e.* towards the fountain-head of the oceanic currents, which are propagated northward in periodical undulations, and are called tides. Thus we observe forces, acting on a vast scale, and through unknown periods of time, yet with a definite polar direction and energy, causing the existing forms of the continents and grooving the channels of the oceans between. The great preponderance of land in the northern hemisphere, and of water in the southern, shows the effects of the northerly movements on the crystalline masses. From the same cause no inland seas can be affected by tides; the bays open to the south are exposed to the maximum, and those open to the north to the minimum effects of the tidal waves.

Thirdly.—The grain of the primary crystalline presents a polar structure in all parts of the world, thus showing the universality of the action and its constant influence in the arrangement of the internal elements. The modification in the transitions of the different rocks, the elongation, fractures and dislocations, show also the general northerly movement of the whole surface.

Fourthly.—Volcanoes and earthquakes appear to be the effects of the chemical action and meridional force of the magnetic currents, according to observations made in South America.

Fifthly.—The formation of mineral veins, their general character, order, and numerous dislocations, prove the action of a polar force; the constant operation of which is essential to account for the observed subterranean phænomena. And if further proof was necessary, we have it in the fact, that it is by means of the laws of terrestrial magnetism alone that we can predict correctly the conditions of any unexplored mineral ground in the primary series.

Sixthly.—This northerly movement co-exists with the formation of our globe, inasmuch as it is the very power that forms a spheroid; it is the increased density of the currents at the poles which is the cause of its oblate figure; and its circulating currents perpetually change the surface of the earth, by bringing the consolidated masses, as they are formed in the southern hemisphere and other parts of the globe, towards the north pole, and thus exposing them to the temperature of different zones progressively; consequently we find the relics of the southern in the northern hemisphere. Such series of beds are never found in the south, nor is the order of the deposits ever seen inverted. Therefore there is no necessity to invent strange hypotheses to account for the observed facts, but simply to apply the natural operations of nature, *i. e.* the prime mover of terrestrial physics —magnetism, to guide us in our geological researches. The striking and unequivocal order in the organic contents of the sedimentary series is such a coincidence with the natural effects of the polarity of our globe and the various animated covering, as to be alone sufficient to establish the fact of the northerly movement.

Therefore since this power is so extensive, and is the cause of what we call gravitation, its operations are not confined to our globe, but also the whole solar system; and if all space is filled with the magnetic powers of the different celestial bodies according to their respective magnitudes, their movements must be explained very different to the commonly received hypothesis.

CHAPTER XXVIII.

THE PRINCIPLE OF UNIVERSAL MAGNETISM OR POLARITY OF MATTER.

WITH regard to the absolute diameter of the terrestrial magnetic power which binds our sphere, there are no data by which we can ascertain it; but from the physical connexion of the moon with the surface of the earth, proved by the phænomena of the tides, sap of the vegetation, meteorological influences, and also that observed in the animal world during the lunar changes, together with her orbital motion round the globe, we have reason to suppose that it extends to the orbit of the moon.

To form an adequate notion of the surrounding atmosphere, we must consider it as an aërial shell extending to the orbit of the moon, wrapped round the globe by its magnetic power and revolving with it. The air is dense on the surface and supported by the ocean and dry land; and graduating into extreme tenuity as it extends towards the lunar orbit. Within the great sphere thus encircling us, invisible but for the gathering of its aqueous part into clouds and vapours, occur those incessant actions and internal changes to which we have adverted.

If, then, the aërial ocean, with its magnetic power, extends to the moon, we may presume from analogy that the satellite floats upon it, and may possibly be carried round the earth by means of a circular current; and that the planets may be sustained and revolve round the sun on the same principle, as they all circulate round that body in the same direction. The sun rotates on an axis nearly perpendicular to the orbit. In round numbers, fourteen rotations of the sun impart one orbital revolution to the earth; twenty-eight rotations of the earth impart one orbital revolution to the moon, and all in the same direction, *i. e.* from west to east. Here, then, we have an analogy with what we see produced by circular motion of fluids, moving in one definite direction by a prime mover; the slower and more majestic movement corresponding with greater dimensions of machinery, and thus impressing on us the prevalence of an harmonious law of action and circular movements, and not mere accidental compound of forces produced by the casual meeting of two forces arbitrarily assumed. Besides, we find constant parallelism of the earth's axis with the axes of the planetary bodies, and we have also experimental proofs of the rotation of magnetic globes by galvanic currents corresponding to the rotation and revolutions of the planets; hence the analogy is complete. We know that bodies may be sustained at any elevation in the air, as well as in the ocean, by adjusting their densities to that of the stratum of fluid in which they may be placed; and that such bodies, like the balloon in the air, or a vessel on the ocean, would continue to revolve uniformly round the earth by a circular current. This is consistent with our daily experience, and according to the well-known laws of nature. No one would presume to say that the clouds are retained in their positions by means of centrifugal forces, and that they would fall towards the earth if such forces were removed. As nature is considered always conformable to herself, we have no right to assume powers different from those that exist; therefore we have no reason to suppose that the moon is retained at her respective distance from the earth by a power different from that which retains the clouds. The moon, as well as the earth, may be filled with hydrogen, or with still lighter gas for aught we know to the contrary, and which is an opinion infinitely more probable than that of its being filled with igneous matter; consequently a shell containing such a gas enveloped with an atmosphere kept together by the magnetic attraction, would render the moon sufficiently buoyant to float on the external part of the terrestrial aërial sphere.

On the Laws of Motion applied to account for the Circular Movement of the Heavenly Bodies.

Mathematicians think that celestial bodies are sustained in their orbits by means of an original impulse given to them, combined with a centripetal force, and not according to the principles we observe in terrestrial physics; they have laws of motion peculiar to themselves, which have been assumed and blended with the laws of geometry. Indeed, so far as physics are concerned, it matters not much what hypothesis may be adopted in astronomical phænomena, provided our calculations be founded on uniform spaces and velocities; as the whole are reduced to the laws of proportion which subsist between sines and cosines, and not in the least depending on the laws of physics*. Admitting in the abstract that such a space as a perfect void existed, and that a body placed in it would remain for ever at rest; should the body be put in motion by an external force; not a vital principle, nor means of generating a force, but one impulsive action; what would be the consequence according to the established laws of nature founded on experience? According to terrestrial physics, experience and analogy, all impulsive or projectile forces which cannot accompany a body thrown into space, depend on the expansion of a power previously concentrated: the length of the path through which it will be carried can only be equal to the amount of power communicated. A boiler full of steam (or gas) is a power, but cannot produce any action without expansion; but immediately on allowing it to expand it will produce effects proportionable to its density, the force of which, if not supplied by some generating power, will diminish inversely as the cube of the volume increases in space. The ultimate extent of the expanding power carrying the film or body need not be considered, but its variable force and velocity; these are the questions at issue.

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* Many persons who read and admire the degree of correctness of our almanacs in predicting the eclipses, tides, &c., suppose that such predictions are founded on the law of gravitation; but the fact is that such calculations are entirely dependent on the direct observations of the periodical movements of the heavenly bodies, &c., and have nothing to do with the physical theories of the universe. The ancients made similar calculations at a period when their doctrines were very different.

We know, and it has been proved experimentally, that an impulsive force, which is necessarily limited in its amount, has an evanescent quality, and consequently any body or point carried by it commences with a maximum force and velocity; it cannot describe equal spaces in equal times; "like causes produce like effects, or, in similar circumstances, similar consequences ensue;" the force must therefore diminish, and consequently the velocity, inversely as the volume increases, until it finally arrives at a state of rest, *i. e.* a state of equilibrium between the limited impulsive power imparted and the actual effect produced. Indeed engineers are so much accustomed to the above law of forces that it requires but little comment.

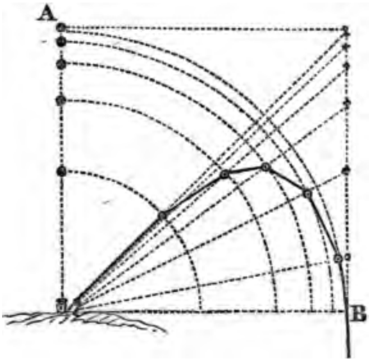
When a ball is discharged, it is not the mere resistance of the air and the earth's attraction that reduces the velocity and brings it into a state of rest; it is the *evanescent quality* of that power which had put it in motion: the resisting medium and the attraction of the earth only *diminish the extent* of its path. According to the doctrine of gravitation, neither the radial attraction of the planets, nor a resisting medium, has any influence on the impulsive effect: on the contrary, it is made both *continuous and uniform*, an effect totally inconsistent with the known principles of physics. Had such a doctrine of the laws of motion been founded on correct data, we should have no difficulty in effecting a perpetual motion. What an amount of ingenuity, labour and expense, have been thrown away on the pursuit of the perpetual motion, which might have been turned to better use, if the simplest laws of terrestrial physics had been consulted instead of mere geometry, *i. e.* that no motion can take place and continue without the presence of an active principle! It is time to remove the mist which has so long enveloped physical science, and sweep off some of those intricate calculations which have obstructed the path, and make it easy and clear to all. Natural philosophy may thus become regarded as it ought to be, a fountain of intellectual recreation capable of being enjoyed by all, to the injury of no one; on the contrary, adding to the practical aid and advantages of our fellow-creatures, cherishing an unbounded spirit of inquiry, free from all prejudices, and open to every impression of a higher order, and affording at all times the purest earthly happiness of which human nature is susceptible.

The following extract from a standard work on astronomy, written by one of the first philosophers of the day, will at once show on what foundation the orbital motions of the 'Principia' are based, and how geometrical curves and the paths of projectiles have been confounded.

"All bodies with which we are acquainted, when raised into the air and quietly abandoned, descend to the earth's surface in lines perpendicular to it. They are therefore urged thereto by a force or effort, which we term *gravity*, and whose tendency or direction, as universal experience teaches, is towards the earth's centre; or rather, to speak strictly, with reference to its spheroidal figure, perpendicular to the surface of still water. But if we cast a body obliquely into the air, this tendency, though not extinguished or diminished, is materially modified in its ultimate effect. The upward impetus we give the stone is, it is true, after a time destroyed, and a downward one communicated to it, which ultimately brings it to the surface, where it is opposed in its further progress and brought to rest. But all the while it has been continually deflected or bent aside from its rectilinear progress, and made to describe a curved line concave to the earth's centre, and having a *highest point, vertex or apogee,* just as the moon has in its orbit, where the direction of its motion is perpendicular to the radius. When the stone which we fling obliquely upwards meets and is stopped in its descent by the earth's surface, its motion is not towards the centre, but inclined to the earth's radius *at the same angle as when it quitted our hand.* As we are sure that, if not stopped by the resistance of the earth, it would continue to descend, and that *obliquely,* what presumption, we may ask, is there that it would ever reach the centre, to which its motion, in no part of its visible course, was ever directed?

"What reason have we to believe that it might not rather circulate round it, as the moon does round the earth, returning again to the point it set out from, after completing an elliptic orbit, of which the centre occupies the lower focus? And if so, is it not reasonable to imagine that the same force deflects the *moon* at every instant from the tangent of her orbit, and keeps her in the elliptic path, &c.? . . . . It is on such an argument that Newton is understood to have rested his law of gravitation *."

If a body thrown up at a certain angle, say 45°, will descend again at an angle of 45°, it follows that if thrown sufficiently high it would escape the earth altogether, and possibly revolve round it: but what is the *fact*? It is, that bodies *do not* return at the *same angle*. Suppose a stone was thrown up at an angle of 45° with a force which would carry it to an elevation of 500 yards, it would on its near approach to the earth descend almost *perpendicular*. It commences with its maximum angular force, which exceeds that of the radial attraction of the earth proportionably to the sides of the parallelogram of which its path is a compound; at its greatest elevation the radial attraction and the impulsive force are in a state of equilibrium; as the latter rapidly decays, the former being constant and accumulating, the stone returns, and the angular or tangential force becomes evanescent, until at length the stone is left to the sole action of the radial attraction of the earth, and therefore must proceed towards the centre. Those who may not feel disposed to prove the above mathematically, or who may prefer having an ocular demonstration of the fact, may have an illustration in the path of a stream of water forced by a strong pump at a given angle, when it will be observed that the curve of the stream of water, instead of forming the same angle at each extremity, will be very different. The impulsive force will be exhausted at A and B.



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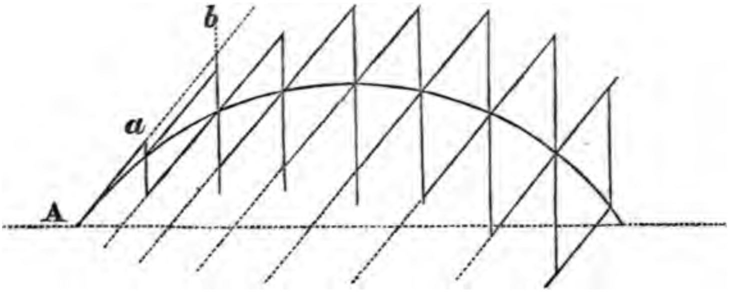
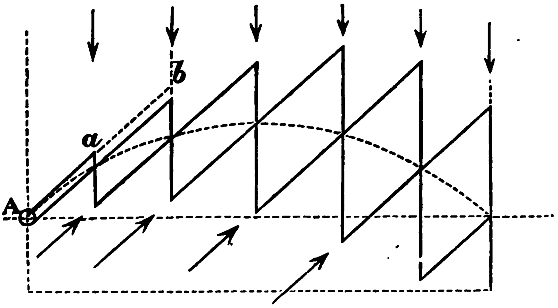
* Herschel's Astronomy.

To suppose that the moon is retained in a circular path round the earth by a *projectile force*, is contrary to analogy, and cannot be demonstrated.

The parallelograms commonly described of the composition of the projectile and gravitating forces, are very erroneous; and it is somewhat surprising that they have not been long ere this corrected. A projectile force can neither be constant in direction nor uniform in velocity throughout the curve described.





According to the *theory of projectiles* taught in schools, it is supposed that "if a cannon-ball be shot from A in the direction A *b* (described above), and its original velocity be such as would carry it through the space A *a* during one second, then, if not subject to gravity, it would proceed in a straight line and arrive at *a* in one second, at *b* in two seconds, and so on. Gravity would cause it during the first second to fall sixteen feet, and by completing the parallellograms the following arc is described," and by means of such assumptions it is supposed "that the ball moves in a curve and falls in the same angle as projected."

In the above parallelograms we can readily admit the parallelism in the vertical action of gravity, within the range of a cannon-ball, but we cannot conceive how a force emanating from the cannon's mouth, fixed to one point, and only capable of imparting that force at that point, could act in the oblique parallel lines shown in the figure. In the vertical direction we find the space described by the ball gradually diminished, until at length the upward force is exhausted, and the ball brought back solely by gravity. Why should the projectile force be constant and uniform at an angle of 45° ?

After entering into various formulæ and theoretical deductions, we find the following observations:—

"In all these calculations the air has been neglected; the introduction of which complicates the problem so much as to render it one of the most difficult in dynamics, and one which *cannot be said to be even yet reduced to a practical form.* The calculations of gunnery are therefore *necessarily founded on experiment* rather than theory. According to theory, the path would be a perfect arc at each extremity; whereas, in the actual path of a projectile, the descending branch is always shorter and steeper than the ascending one, *and falls more perpendicular.*"

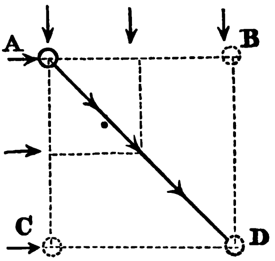
This requires no comment; it is like the theory of the tides, and many others, valueless in practice: it will be observed by the preceding diagram that the ball must necessarily drop nearly vertical on reaching the ground. Besides, were we to grant even the construction of such parallelograms, it would be impossible to make a complete circle, so as to bring the ball back to the point whence it was projected.

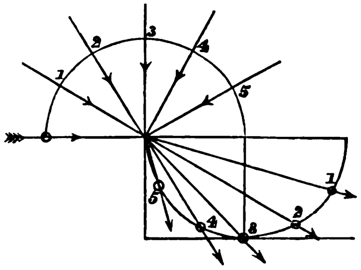
If, then, we find that a body put in motion by one impulsive action must ultimately come into a state of rest without any resisting medium, how much sooner must it exhaust its force if opposed by other forces, and especially if the latter should be constant! A straight line divided into equal parts is one thing, but to produce a force to describe such parts in equal times is another; the former is controlled by the laws of geometry, the latter by the laws of physics. This is the secret link which has been used to preserve the curvilinear doctrine of gravitation; without which tie it could not stand, and must be well known to those who have studied the 'Principia.'

It was once proposed as a prize question by the Academy of

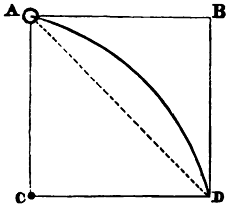
Science at Berlin, to determine whether the laws of motion were necessary or accidental; that is, whether they were to be considered as mathematical or as physical truths. An attempt was made to deduce them from a metaphysical principle of the minimum of action in a very complicated and fanciful nature, the intricacy of which only tended to envelope the subject in still greater obscurity; while the fundamental laws of motion are easily demonstrable from the simplest physical truths. Motion is a change of place, which matter cannot possibly effect of itself; motion is not a property of matter; it can only take place during the excitement of some active principle, and the space described is the measure of the amount of power consumed.

We find that the diagonal of the parallelogram of two forces represents the magnitude and direction of the compound; but we must always bear in mind the distinction which exists between *statics* and *dynamics*. In the former it matters not how the sides of the parallelogram are accumulated, whether slow or quick, by small quantities or by large quantities; as long as the amount of the forces is represented by the length of the sides, a straight diagonal will represent the compound when in a state of equilibrium. The laws of dynamics are not confined to the extreme limits or the mere gross amount of the forces, but they embrace also the nature of their accumulation; we have to analyse the component parts and consider them in connexion with space and time. Speaking *geometrically*, the sides of the parallelogram may be of equal length, and therefore contain an equal number of parts; but that is no reason that such parts should be described in the same time. *Time* is another element, and independent, having no necessary connexion with pure geometry; it belongs to physics, and if we combine the movements of one with the laws of the other we must do it legitimately. The laws of proportions of one are definite and unalterable, whilst the movements produced by the other may be modified according to circumstances. If we describe a circle, we find it in its usual exact proportion; if we apply motion and time to describe a circle, we must adopt them for it, *i. e.* according to their own peculiar properties, and not *solely* by geometry. We are told that the planets are retained in their orbits simply by means of two forces, the tangential and centripetal; and that if one of the two forces were taken away, these bodies would be either carried off in a tangential direction, or fall to the focus of the centripetal action. If a body put in motion by a uniform force in one definite direction be met by another body moving at right angles to it by a similar uniform force, they will form a compound at the point of contact, which will be equal to the diagonal of the parallelogram of the two forces, in direction and magnitude; and as their respective forces were uniform, the compound will be uniform and straight, as described in the annexed diagrams:—

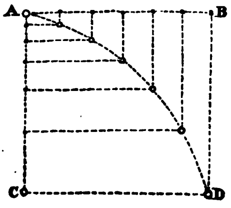




If the perpendicular be an increasing force and the horizontal a uniform one, the following curve will be described:—



This arc will be formed by an increasing velocity until the body arrives at D, where it will require another tangential force at a right angle to the direction of the former to complete a semicircle, and also corresponding parallel lines of gravity instead of the radial to describe the parallelograms, as the following figure will show:—



Suppose the body set in motion by an impulsive or a variable force be met by a uniform force, the diagonal will be described by a variable velocity, and in a curvilinear direction. If the two forces be variable in the same ratio, the diagonal of the parallelogram will be straight, but described by a variable motion. If we require the compound to form a *circle,* and to be described in *equal times and spaces,* the radius and velocities remaining constant quantities, the centrifugal and centripetal must be constantly equal; but in order to form the circle the tangential must possess the power of *perpetually changing its direction,* in a word, a *circular motion;* without this the orbit cannot be described by the compound. The continuation of the parallelogram beyond the quadrant would at once show the necessity of a fresh impulsive force applied at right angles to the former; and the circle is even then of variable velocities in each quadrant. It is therefore made evident that such conditions are not only contrary to the laws of terrestrial physics, but also contrary to the compound of the assumed forces.

It must not be forgotten that an arc, although bounded by the same extreme limits in a parallelogram, however small it may be reduced, cannot be considered as a straight line. Any attempt of making rectilinear and curvilinear figures equivalent by reduction, must be considered as merely merging into indivisibles and inadmissibles, if there be any truth in the laws of geometry. Indeed the question on the condition of forces necessary to produce given effects is clear and divested of all metaphysical obscurities, not requiring the differential calculus, and other methods of geometrical analysis that are so objectionable in their logic and conclusions. All we require to account for the moon being retained in her orbit, and the planets again in the atmosphere of the sun, and all moving in one definite direction, is the admission of magnetism, *i. e.* that mysterious power which we *know* to exist, circulating from pole to pole of every individual body, with a power varying inversely as the square, or rather as the cube of the spheres, rendering the respective compounds or fluids of each body of variable density; and this again accompanied by an equatorial current or circular motion; being an essential property of magnetic forces.

The application of the Newtonian laws of motion to the comets is still less satisfactory than it is to the planetary bodies. The comets appear to be gaseous bodies as rare as vapour; yet it is assumed that bodies so light move towards the sun, and pass through its dense atmosphere by means of tangential and centripetal forces. Conceive a body, say a feather, to be drawn from a distance by means of a radial power increasing in force inversely as the square of the distance diminishes, and that it should arrive at the focus of such an intense radial power, and then turn round and move again from it, simply by means of the velocity generated in moving towards it, and thus continue to circulate in an elongated ellipsis round such a centre: it is contrary to all analogy: and it is truly extraordinary that such notions should have been encouraged for one moment. If we apply magnetism, and assume that the sun is governed by a similar power, we have no difficulty in explaining the nature of the motion of comets. According to the laws of magnetism, a combination of magnetic globes in a state of equilibrium will have their respective poles dissimilar, *i. e.* the north end of one corresponding to the south end of the other. Hence it follows that the pole of the moon corresponding to our south pole must be the attractive, and that the pole of the sun corresponding to our north pole must be the repulsive. If a comet were a luminous vapour, like the aurora borealis, moving by the polar currents of the sun, it would necessarily move nearly at right angles to the orbit; and such are their paths. If, again, we consider them as mere solar magnetic sparks, they must be conveyed by the polar current to the attractive pole, and issue out again at the negative pole, and thus continue their circular motion from and to the axis of the sun by the magnetic currents of the solar system. The light of the sun is too intense to examine minutely the effects of these bodies near it; however, we find that in passing through the axis they present the appearance of a solar aurora borealis and australis.

Their variations in apparent size during the time they continue visible, are no less remarkable than those of their velocity: sometimes they make their first appearance as faint and slow moving objects, with little or no tail; but by degrees accelerate, enlarge, and throw out from them this appendage, which increases in length and brightness till they approach the sun and are merged in its beams; after a time they again emerge on the other side, receding from the sun with a velocity at first rapid, but gradually decaying. It is after thus passing the sun, and not till then, that they shine forth in all their splendour, and that their tails acquire their greatest length and development, thus indicating plainly the action of the sun as the exciting cause of that extraordinary emanation.

A similar circumstance has been remarked also in the change of dimensions of the comet of Encke in its progress to and from the sun, viz. that the real diameter of the visible nebulosity undergoes a rapid *contraction* as it *approaches*, and an equally rapid *dilatation* as it *recedes* from the sun, owing probably to its passage through the axis. Cometary bodies may appear, in looking at them in the heavens, irregular and capricious in their paths; but a careful observation will show that they uniformly move to the same pole and emerge from the opposite; and more or less at right angles to the orbits. They may also pass through the axis of the planets in a similar manner, thus producing the phænomena of the aurora borealis and australis.

To conclude, we may reasonably consider that by this power the stability of the solar system is maintained, and the form of the celestial bodies shows that it is an active agent in each. Nor is this universal power confined to our own system, but extends as far as telescopic vision can determine in the immensity of the works of the creation. This wonderful power is present in all things visible and invisible, like a mysterious and universal spirit controlling the vast works of the universe. Yet although so great and so various in its effects, its laws of action are so simple as to be within the reach of our comprehension. It is like a wheel within a wheel working myriads of other wheels within its sphere of action; we find it in the minutest microscopic crystal, in the aggregation of crystals which constitute a continent, in a word, in our globe bodily; this again governed by the magnetism of the sun, and probably the sun by a still larger body, until we are lost in its immensity. It is vain to proceed further; the more we progress into the regions of space the deeper we merge into the impenetrable mysteries of the creation, and the greater becomes the diameter of the surrounding darkness, which expands far beyond the sphere of human imagination. Although the harmony and uniformity of the system may be thus preserved for ever, exhibiting no change, no beginning nor ending, yet we find in our terrestrial habitation, *i. e.* the earth, the seat of man, that it is but the production of a season, and subject to decay like animated nature: the spot on which we exist will by the same harmonious law, independent of the globe itself, ultimately disappear, and be reduced to its primary elements at the north pole. Great Britain, and other countries which are situated in the same parallel, will in a very few thousand years vanish from the surface of the globe, and other more southerly lands will take their place. As already stated, the electro-magnetic power which controls our planet by the circulation of its movements, renders the southern hemisphere the spring of our terrestrial habitation, the equator its summer, the northern hemisphere its autumn, and the north polar basin its final dissolution. Hence geology and magnetism is a science that cannot be surpassed in the magnitude of its utility nor in the sublimity of its objects: not only is it next to astronomy, but it forms one and the same system of physical operations; and instructs us that we are placed in a part of a scheme—not a fixed but progressive one—ever-changing—no permanent resting-place, one generation passing into another by succession, and merging into eternity—every way incomprehensible; incomprehensible in a measure equally with respect to what has been, what now is, and what shall be hereafter to the end of time.

CHAPTER XXIX.

ON THE GENERAL APPLICATION OF THE LAWS OF TERRESTRIAL MAGNETISM TO THE USEFUL PURPOSES OF LIFE.

NOTWITHSTANDING the existence of magnetism has been so long known, and turned to account in navigation and general surveying, and has been the subject of numerous experiments and theories, the application of this principle, beyond that of the above, has been of a nature purely local, confined to mere toys, until very recently, and never has been duly considered in the magnitude of its effects and universal character in the manner now brought forward. A detail of all the various useful application of which this universal principle is susceptible, would occupy volumes, as it embraces all phænomena now classed under the head of gravitation; it has an intimate connexion with our proceedings, we are at all times enveloped by it and permeated with it, and we are always under the immediate dominion of its laws, which laws are found permanent, consistent, intelligible, and discoverable with only a moderate degree of research. Hence, since it is certain that such a principle exists, it is manifestly of the utmost importance to study its laws and to know how to apply them, were it for no other reason than to enable us in all we undertake to have at least the laws on our side, so as to avoid struggling in vain against difficulties opposed to us by natural causes.

It is the variation in the density of the enveloping magnetic fluid which is the cause of pendulums of equal length varying in the number of their oscillations in a given time in different latitudes; and in order to make them keep correct time, it is necessary to vary the lengths respectively according to the variation in the intensity of the radial attraction in each latitude. We find also that the zones of equal density in the atmosphere are not at equal heights in different latitudes, and therefore in making barometrical measurements the formulæ should be made to correspond to the variation in each latitude*.

The *polarity* of terrestrial magnetism is the mariner's faithful guide when enveloped in darkness on the boundless ocean; and he knows that if masses of iron be placed near the magnetic needle it becomes disturbed and rendered useless. The knowledge of the cause of such disturbances for its safe application is as essential as that of the principle itself; and still more so, as it will protect its possessor from being misled by inventions which pretend to neutralize the effects of local attraction. The law of magnetic action will show what is within the limits of possibility and what is not; and that the less the natural current is disturbed, the more correct must be the indication of the needle.

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* Whilst making my barometrical observations near the equator, I found that the old formulæ were of no avail, and I was obliged to make a new table for determining the correct elevation by the barometer.

We are to consider magnetism as a stream of subtle fluid constantly moving from south to north; should it be disturbed from its natural course, nothing short of the removal of such disturbances can give its true direction. The author made several experiments on this subject on the Pacific and during his voyages from South America to England; therefore he speaks from experience, as well as from deductions founded on experiments. The most important points to be attended to are the following: to make the needles in the best form for retaining their magnetism, and in such a manner as to allow the currents to enter and issue out at two points diametrically opposite, *edgeways* and not flat, and that the current may pass through without being interrupted by a dissimilar metal; and to place such needles in situations sufficiently distant from local disturbances*.

Variations.

The charts of magnetic curves of variation are drawn at present in a manner that tends to mislead persons. Instead of laying down the direction of the needles as they would naturally appear when left to the sole control of the magnetic stream in their undulating meridional lines, they are marked in the most confused manner with irregular inflections of curves, indicating a total want of symmetry, and thus complicating the question of variation by lines which have no necessary connexion, productive of no advantage, but of much real injury to the problem itself. On reference to a chart, it will be observed that it contains two distinct lines, which are called lines of no variation; the western passing in a north-west direction from the South Atlantic Ocean to a point *called* the magnetic pole, round which a series of lines are drawn, having the appearance of a general convergence towards it, which on a superficial inspection leads to the idea that they represent the actual direction of the horizontal needle, which is by no means the case: what is called the eastern line of no variation is much more irregular, being full of loops and inflexions: it begins in latitude 60° south, below New

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* A vertical stream has a more powerful and correct polarity than a flat one, analogous to the vane which indicates the direction of the wind.

Holland, crosses that island through its centre, and extends through the Indian Archipelago with double sinuosity, so as to cross the equator three times: it then stretches along the coast of China, making a semicircular sweep to the west till it reaches the latitude of 71°, where it descends again to the south, and returns northwards with a great semicircular bend, which terminates in the White Sea. In the Pacific Ocean we find elongated ovals described; what the centre of such ovals intends to represent it is difficult to imagine. Such is the confused manner in which the direction and variation of the magnetic needle are represented. If the chart were compared with Plates IV. and V., on which the same magnetic meridians are indicated by the arrows, it would scarcely be believed that they represented the phænomena intended to be described by these charts. It is to be hoped, for the sake of mariners as well as for the progress of science, that the lines will be shown in their simple natural state, and that the phænomena will not be confused with unmeaning lines, to suit formulæ which can never be of any utility.

Magnetic, or Electro-Magnetic Currents.

It may be supposed from the apparent facility with which some persons attempt to account for the numerous natural phænomena, and so readily state that they are the effects of electricity, and by their *positive* and *negative* terms employed and transposed according to fancy, that there is some *positive* meaning in their notions of electricity.

Notwithstanding all their writings, few of them are able to give a satisfactory answer to the simple question, 'What is electricity?' nor yet a definite meaning to the terms positive and negative. It will be observed that this work is confined more or less to what we know and what we can prove by experiment; and also such as we are able to apply usefully in practice, thus demonstrating the truth of the general principles. It has been shown in Chapters I. and II., that the currents move from south to north in the magnet; that they move from the zinc plate to the copper or silver plate in the battery; and that the two ends or two poles absorb at one end and evolve at the other, and thus continue while the exciting cause is present.

By knowing this, we can apply the current not only to decompose and recompose according to the direction in which it acts, but also to etch steel plates. It has been shown that when the connecting wires of a battery are brought together a spark ensues, and portions of that piece of metal communicating with the zinc are transferred to the metal communicating with the silver. From a steel plate attached to the copper wire of the zinc in a moderate-sized battery, with a platinum- or gold-pointed end to the wire connected with the silver plate, the following results may be obtained. In moving the latter along the face of the steel plate, a portion of the steel face is thrown off and transferred to the etching wire, by means of the intensity of the stream coming out of the steel and drawn into the pointed wire, whence it is conveyed towards the silver plate to be evolved: thus, by electro-mechanical skill and a knowledge of the laws of action, a perfect device can be made upon the hardest steel. If the plate and tracing wire be connected to the reversed plates of the battery, the effect is different; the current rushes out of the platinum or gold point from the zinc, and the latter flies off and is precipitated on the steel plate, thus forming any design in relief that may be traced. Numerous other effects may be noticed; but the above, with the previous illustrations, are quite sufficient to show the importance of comprehending the laws of action.

When the electric telegraph was first employed, it was thought necessary to fix two wires, viz. one for conveying the current from pole to pole, and another to bring it back again. It was supposed that the very same current which issued out from one pole must be brought back again to complete the circuit. The conductor through which the electrical current circulates must be absolutely complete in all its parts to produce the action from pole to pole; no action can be produced without a metallic connexion, the slightest want of continuity of the conducting material between the plates of the battery being fatal to the passage of the fluid. When this is done, all that is wanted to complete the circuit is to convey the wires from each pole to subterranean water connected with the sea, a river, or a well, so as to return back to the aqueous element that active power which is taken from it at another point, it being as it were a reservoir in which the power exists, and not the mere conductor of the same current back again, as some have imagined. If we substitute the electro-magnetic machine for the galvanic, the effect will be precisely the same.

Again, with regard to magnets, we find that a portion of the currents passing through a very short and stout bar returns from the evolving pole back to the absorbing pole; but if lengthened to an indefinite extent, no such returning action takes place; the external enveloping power is absorbed at one pole, and issues out at the other to restore the equilibrium of the surrounding space*. Thus, by paying due attention to the great *laws of action,* and not wasting our time in speculating on the *origin* of things, we rightly keep the mind within the limits of experimental demonstrations and usefulness, making the progress of science more acceptable and more readily appreciated by the community at large. It is pleasing to find that the hints given in the first edition of this work (in 1844) have led to improvements and simplicity in some of the electric telegraphs, which were duly and kindly acknowledged, many years ago, by Mr. Brett and others; and doubtless further improvements will yet be effected in this most important and rapid means of intercourse between different parts of the world.

The innumerable observations and experiments which have been made during the last thirty years, especially by Mr. Faraday, have proved the universality of the electro-magnetic fluid, that it is ever present, and that the existence of a *vacuum* in the universe is not only purely imaginary, but contrary to all demonstrable evidences, in celestial observations as well as terrestrial.

Huyghens's "undulatory" theory of light, which has superseded Newton's "corpuscular" theory, renders it necessary to assume the existence of a *universal fluid* in the surrounding space; hence the supposed vacuum and the perpetual mechanical motion founded thereon must be ignored as no longer applicable to account for the circular and uniform motions of the heavenly bodies from projectile actions in a resisting medium.

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* If great intensity of action be required, the two poles must be brought together as in a horseshoe magnet. By bringing the absorbing and evolving ends near each other, their respective powers become increased proportionally to the compression of the etherial volume entering or issuing out of the poles respectively.

Even the most staunch supporters of Newton's principles of natural philosophy are now obliged to acknowledge that his views require correction. Sir J. Herschel remarks in *Good Words*, in the article "On Light," that Newton's theory of light "has many weak points;" "it runs counter to the only analogy which the observation of nature furnishes;" and adds that "the sturdiest philosophy may fairly be staggered at his postulate as the foundation of a physical theory." It is gratifying to observe that even "Cantabs" are beginning to give way and to assist in removing the obstructions which have so long resisted the march of scientific truths and demonstrable facts.

It has been proved that attraction and repulsion can only be communicated to a distant body *through the medium of an intervening fluid*, and that the magnetic fluid permeates all substances, and cannot be removed by human means. Therefore we have every reason to conclude that the celestial bodies with their sublime order and movements do not depend on the assumed and arbitrary mechanical motions in *empty* space, to sustain and move them in circular paths, but on electro-magnetic forces and the invisible and attenuated fluids with which the solar system is filled, and the separate concentric shells of fluids with which each planet is again enveloped, each forming as it were the ancient idea of a crystalline orb. The laws of refraction, founded on the spherical atmospheric lens, as indicated in page 128, lead to the same conclusion, that each celestial body has its own sphere of aërial, aqueous, and magnetic fluids, separated by a definite spherical surface from the solar fluids in which all the planets are sustained and float, and are carried in circular orbits in obedience to the prime mover of the celestial mechanism. (See page 173.)

Tides.

It is well known that Kepler was the originator of many of the *un*demonstrable hypotheses which have been handed down to us as fundamental physical theories, which have unfortunately become established, through the application of the principles of geometry to Kepler's assumptions by Newton and La Place. It was Kepler who first suggested the so-called theory of the tides. He thought that the moon acted on the ocean somewhat similarly to the action of a magnet on iron filings, and thus attracted the sea and formed large tidal waves each time the satellite passed the zenith and meridian of any given place, and that the sun, in like manner, produced similar effects, but not of equal amount. He *imagined* that there were meridional swells in the ocean within the tropics, and the action of the tides has since been graphically represented in accordance with this hypothesis.

In his "Introduction to the Physics of the Heavens," he endeavoured to explain the cause of the phenomena in the following manner:—

"The orb of the attracting power, which is in the moon, is extended as far as the earth; and draws the water under the torrid zone up into high ridges in places where the orb is vertical; especially in the ocean, whose beds are large, and the waters have the liberty of reciprocation, that is, of rising and falling; but insensibly in confined seas and bays"* . . . . "The cause of the tides, therefore, appears to be the bodies of the sun and moon drawing the waters of the sea."

Sir Isaac Newton took this suggestion without investigating the assumptions on which the theory was founded, and endeavoured to demonstrate its truth by means of pseudo-physical geometrical principles. However, the theory remained unsatisfactory, and was again amended, by La Place and others, without referring to the real movements of the tidal waves (see p. 147).

At the present time, after repeated amendments of the theory by mathematicians, it is all but abandoned, and considered worse than useless.

As a kind of apology we are informed that "the actual phenomena cannot be expected to be in strict agreement with what they would be if no dry land existed." We are therefore entirely dependent on observations to predict the time of high and low water, and to determine what is called the "establishment of the port."

It has been explained in the Introduction and Chapter V. that *the tidal waves commence within the Antartic basin*, and expand and progress therefrom in undulating rings towards the equator, and *are not*, as assumed, *meridional ridges.* Were the globe entirely covered by the sea, these undulating waves would move northward in parallel waves; becoming flattened at the equator as they extended in circumference, and increasing again in their height as they converged in approaching the Arctic circle.

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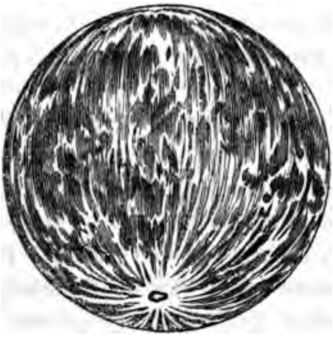
* The highest tides are found in channels and bays *open to the south*, and not in mid-ocean.

The configurations of the coasts of the dry lands necessarily break the uniformity of these tidal waves, and thus cause their progress northward to be very irregular, as described and illustrated in the Introduction.

In rising and expanding from the antarctic circle, the flood tide impinges upon Chiloe and the adjacent outer coast from the S.W. At the eastern part of Falkland Islands it is high water at 9 p.m. F. and C., and on the south shore of Tasmania it is high water at 10 p.m.,—two places nearly opposite. At each of these places the tide rises six hours and falls six hours alternately.

The cause of these tidal waves appears to be the electro-magnetic action of the *visible pole of the moon* (which is always south) on the south pole of our globe: the tidal waves vary according to the position of *the lunar polar axis* and its alternate illumination by the sun. The annexed disk represents the dark moon at the "change," with the pole below in the direction of the south pole of the earth.



It is well known that the moon always presents the same face towards the earth, whether illuminated by the sun or not; hence we never see but one pole of the moon, which is always pointing towards the terrestrial south pole. The obliquity of the lunar polar axis is double that of the earth, *i. e.* equal to 47°, as may be measured on a good photograph of the moon. Hence the polar axis of the moon in revolving round the earth has a conical motion at an angle of 47° to the terrestrial axis, and thus presents the poles alternately to the rays of the sun, analogous to the changes of the terrestrial poles during a revolution round the sun, which produce the different seasons. At "full" the visible pole of the moon is illuminated; and according to analogy and electro-magnetic experiments, the south pole of the earth and the visible pole of the moon must be dissimilar, therefore a strong action must ensue between them at that period. (See Plate II. on the position of magnetic bars and their respective polar currents.) Again, at the "change" the invisible pole of the moon (the evolving pole) becomes exposed to the sun's rays, and thus increases the intensity of the action between the evolving pole of the earth (the antarctic) and the visible (absorbing) pole of the moon. At the quadratures the poles of the moon are only half illuminated, principally by refraction at the boundary of the "terminator," consequently can only act very feebly. Hence we have *spring tides* at "full" and "change," and *neap tides* at the quadratures. These polar actions of the moon, in connexion with the intervening fluids and the electro-magnetic currents, may be easily illustrated by experiments. The terrestrial magnetic fluid doubtless extends to the moon's orbit, and our satellite is sustained there by it, and is thus attached to the terrestrial sphere, like a balloon or the clouds in our atmosphere.

Steering-Compasses and Iron Ships.

It has been shown in page 2 that the magnetism of the earth will make a bar of iron magnetic if left in the earth a certain time, and that the polarity thus acquired will correspond to the direction in which the bar may be placed. It matters not what size such a bar may be, or how constructed, the effect will be the same. Therefore it follows that an iron vessel will, under similar circumstances, acquire polarity from the earth and the surrounding fluids; and if compasses be placed within the influence of the magnetic currents of such ships, they will be affected and their directive virtue rendered uncertain. From this cause serious errors in steering have occurred; and many shipwrecks are attributed to this disturbing influence of iron and iron ships on the compass.

These very serious disturbing causes can be, if not entirely removed, at least greatly lessened, before the ship leaves the port. This important fact deserves the immediate attention of the Admiralty, the Board of Trade, and the owners of iron ships.

The frequent attempted remedies by the introduction of what are called neutralizing masses of iron and magnets as "compensators" for the ship's "deviation," placed here and there near the compass, increase the uncertainties and the consequent dangers arising therefrom. Neither "compensators" nor tables of "deviations" can be relied on with safety, even in the same latitude as that of the port from which an iron vessel might sail, and much less if bound to higher or lower latitudes. The *polarity* of an iron vessel undergoes so great a change in a comparatively short time, if subject to sail in various courses, as to render it dangerous to rely on "compensators" and tables of "deviation" founded on the observations made previously to leaving port. Several instances may be mentioned of their having led captains astray, especially in the southern hemisphere, and the magnets have had to be removed to avoid further confusion and danger. Daily experience shows that to ensure correctness in steering, compasses must not be tampered with. Soft iron never retains its polarity long, and it may be almost instantaneously neutralized or destroyed by means of the application of a battery. A slight blow with a hammer will neutralize and reverse the polarity of an iron bar. An iron ship's polarity may be sufficiently neutralized by a strong battery, so as not to have any serious effect on a well and properly constructed compass placed at a certain distance from any iron—thus doing away with the disturbing cause and the numerous difficulties represented in the reports of "The Compass Department of the Admiralty."

No weak and badly constructed compasses should be used, more especially on board iron ships. This is a highly important question to be considered, as we have seen many compasses totally unfit for steering-purposes—indeed worthless and dangerous.

The *steering*- as well as the *standard*-compass should be placed from the steering-wheel, and above the deck, at least 10 feet. Although the "*brushes*" of the magnetic currents entering into, and issuing out of, the ends of magnetic needles do not extend more than two feet six inches from the centre of the compasses, yet, to ensure safety and be beyond the reach of any disturbing currents, steering-compasses should not be nearer to any iron than 10 feet. There can be no difficulty in making such arrangements. The author has constructed compasses adapted for such purposes, whose cards may be clearly seen and read like the dial of a clock at a high elevation, and also compasses capable of retaining their *directive* force to a much higher latitude than those now used.

We have now gone through some of the most obvious phenomena and guiding principles of terrestrial magnetism, and their immediate application to navigation. Without a full and clear explanation of the laws of terrestrial magnetism and their connexion with terrestrial physics, the many wonderful and important relations of these laws to the system of the world cannot be appreciated or comprehended.

From whatever source the magnetic force may arise, whether from the sun alone or from a still greater power, that would in no way affect the question before us as regards the *observed* laws by which this mysterious subtle power *operates from pole to pole on earth.*

This universal polar influence guides us, on the boundless ocean, in the darkest nights—a power whose existence was scarcely known not many centuries ago, and probably would still have remained unknown had it not been for the magnet; yet its everlasting silent working imperceptibly changes the aspects of man's habitation—remodels again and again the superficies of the globe, and makes all pass away in succession like a scroll. Thus all things terrestrial are continually merging into eternity, according to the will and ordinance of our Maker.

APPENDIX.

The Gold-bearing Rocks of the World, their Composition and Vertical Meridional Structure.

In the Introduction, and in Chapter VIII. page 49, a general description of the gold formation is given.

It is well known that the author has maintained, for the last twenty-five years at least, that the gold-bearing rocks belong to the fundamental crystalline series, such as the granites, gneiss, schist, &c., and not to the sedimentary or fossil rocks, and that the auriferous variety were composed of quartz, ferruginous felspar, chlorite, talc, &c., and that these crystalline rocks had a *vertical* structure, with a bearing more or less coinciding with the meridian.

These rocks were first described in the 'Mining Journal,' afterwards in the first edition of this work (in 1843), and subsequently in Melbourne, Australia, in a pamphlet, and also in the 'Transactions of the Institution of Civil Engineers.'

Practical men engaged in gold-mining and gold-digging have recognized the correctness of the author's views, and have acknowledged them in their communications from California, Australia, and other gold-producing countries, as the following quotations will show:—

"In the Brazils, especially the northern part, all the gold-bearing rocks are composed of *vertical and meridional bands of gneiss, chloritic and micaceous schist,* enclosing veins of porphyry and quartz."

"In Veraguas and Central America the gold is found in *vertical chloritic argillaceous slate.*"

"In Mexico the gold is obtained from porphyry and *vertical slates.*"

"In Virginia the gold-bearing bands are *vertical* talcose and quartzose slate, bearing 10° east of north."

"In Nova Scotia the gold veins are enclosed in *vertical chloritic slates.*"

"In California the auriferous gravel and clay lie on the edges of the slate rocks. The gold-bearing rocks are composed of chloritic and micaceous slate, *running on their edges in a north and south direction for hundreds of miles.*"

"In the Ural Mountains they have a *meridional direction,* and are of the same composition as the gold rocks of South America."

The author explained and fully described the general character of the gold-bearing rocks, in a series of papers in the 'Mining Journal,' long before the discovery and the Californian excitement occurred, and showed that gold was found in all crystalline rocks of a certain class.

Sir R. Murchison, in a letter with reference to Dr. Cumming's Lecture, October 1861, states that "when fresh from the gold-bearing Ural Mountains, he had the opportunity of examining a large collection of the rocks from the meridional chain of Eastern Australia, and was struck by their resemblance to the Uralian rocks (also a meridional chain), that he publicly expressed his surprise that no gold had been found in our distant colony."

After the Californian gold excitement occurred the generality of the gold-diggers became acquainted with the *vertical* and *meridional* structure of the gold-bearing rocks; and this led them to search and make discoveries in other countries where similar rocks were seen.

Mr. Hargreaves, in his account how he came to suppose that he would find gold in New South Wales, made the following statement:—"The Californian diggings were composed of slates and quartz veins, which generally *ran north and south.* We worked for gold in the drift overlaying the slates, and also found gold in the laminæ of these rocks." . . . . "He had seen the same kind of vertical rocks running north and south in Australia. He knew nothing of geology." . . . . "On his return to New South Wales he searched for gold in the gravel on the same kind of rocks *running on edge north and south,* and immediately found gold."

These extracts are sufficient to show that the auriferous rocks are more or less vertical, with a meridional bearing, as represented by the author in his communications dated as far back as 1838, whilst he was engaged in gold- and silver-mines in South America.

The Provincial Secretary of Nova Scotia, in his official letter, dated Sept. 4, 1861, makes the following remarks:—

"The existence of auriferous deposits in Nova Scotia was unsuspected till 1860, when they were discovered by the returned diggers from California and Australia. It is strange that they should not have been turned up, or escaped the vigilance of the geologists of this country, who have elaborately written thereon." Similar observations were made in New South Wales when Hargreaves and his Californian companions returned to that country, and found gold in the débris of the vertical crystalline works.

"It was very strange," it was said, "that none of the geologists who had surveyed the country had indicated the existence of gold in the primary rocks of New South Wales, and that it was left to be discovered by the returned gold-diggers from California, who knew little or nothing of the science of geology."

This is easily accounted for. Geologists *even at this date* do not appear to understand the true character of the primary rocks and their general structure, much less the gold-bearing rocks. Indeed some eminent geologists have recently actually described the gold-bearing rocks of Canada and Nova Scotia as the Devonian!— hat is, that they belong to the *sedimentary* series and not the primary; therefore we need not be surprised at geologists not having detected the existence of gold when they appear to be unable to distinguish the difference existing between primary slate and sedimentary beds.

Those who feel an interest in the origin of the late gold-discoveries, and what has been said and written on the subject from time to time, should not be guided by the recent accounts and geological compilations, but refer back to the actual papers, books, and their dates, say from 1836 to the present time. It is the only way to arrive at the truth, and to remove the misconceptions now prevailing regarding the gold-discoveries of California and Australia.

Roofing-Slate Quarries.

In Chapter XIII., page 76, a brief description is given of the general character of *roofing*-slate formations. There are two varieties of roofing-slate rocks, viz. (1) the outcrop of the *primary* hornblendic slates, and (2) the altered homogeneous argillaceous *sedimentary* beds, which, in the lapse of ages, have become, by the electro-chemical process, united with the fundamental crystalline base, and thus the old sedimentary divisional planes have been almost obliterated by the vertical action of the cleavage-planes.

The homogeneous and fine-grained roofing-slate rocks vary in structure, from the splintery fibrous to the smooth and finely laminated. All the best slates are situated more or less on edge, and their fibrous or splintery structure is generally vertical. Again, to ensure good and uniform splitting of the slate-blocks, it is necessary to *split them whilst they contain their natural moisture.* Hence we find that the natural cleavage of the rock has not only been produced by a *wet process*, but also that it is essential, to ensure the best results, that the blocks should be split and converted into fine slates before the water with which the rock is saturated be lost by evaporation.

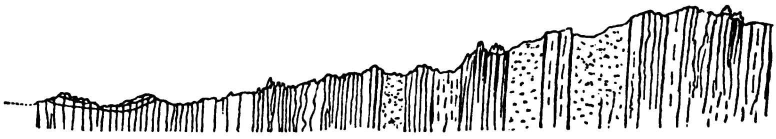
The cleavage structure, as already explained, is common to all the primary series of rocks, from the granites to the slates; but the *roofing*-slate bands have a more uniform, even, and silky grain, and are of a more homogeneous character than the ordinary primary slates. The principal components of roofing-slate rocks are silica and alumina, with oxide of iron, manganese, potash, &c., but varying in their proportions in different localities. Too much silica makes the slate brittle, and too much alumina renders the slate weak and soft.

The bands of roofing-slates in Carnarvon are interlaminated with hornblendic rocks, vary in colour from dark to light green, and, in the valley of Nantlle, are bounded by a kind of laminated granite (gneiss) and porphyry, thus showing their connexion with the primary base from which their structure has been derived.

Plate VI. represents the direction of the slaty rocks of the United Kingdom, showing a bend towards the N.E. from the normal meridional direction. These rocks are intersected by more recent joints approaching the magnetic meridian. The structure of the primary rocks of the north-east of Ireland and the Western Isles of Scotland approach the normal bearing of north and south.

The alleged discovery of Organic Remains within the Primary Crystalline Rocks of Canada.

The primary crystalline rocks of Canada are composed of vertical and meridional bands of gneiss (laminated granite), mica-schist, hornblende slate, silicate and carbonate of lime, quartz, &c., similar to the rocks described in page 46, and illustrated in Plates VII. and VIII. This fundamental formation is called by the Canadian geologists the "Laurentian," and is supposed by them to consist of a series of sedimentary beds turned up on edge, about 30,000 feet thick! Were we to adopt the same view and calculations in South America (see the section of the Andes, Plate VII.), the thickness of the series would amount to about 300 miles! We need not repeat here what has been fully explained, that these rocks are *not* sedimentary beds lifted on edge, but *vertical bands of crystalline rocks,* naturally formed in the position they are seen, as shown below.



Those who have lived for some time within the tropics and the southern hemisphere, and who have studied the growth of coral reefs on the decomposed edges of the primary bands of limestone, the disintegration and reconsolidation of mineral matter &c., would not be surprised at the discovery of a few corals, shells, or marine plants in the *superficial* parts of the exposed *edges* of the crystalline rocks forming the beds of tropical seas, and much less at finding them on the outcrop edges of the calcareous bands, which are subject to decomposition and rapid recrystallization in warm climates. But these remains are not found within the body of the rock many feet below the exposed surface.

It appears that such remains have been lately found in the superficial edges of these calcareous crystalline bands in Canada; and this discovery, in connexion with the mistaken notion that the formation is composed of *sedimentary beds thrown up on edge*, has caused much misconception. The bands of limestone (to the superficial parts of which the organic remains are attached) are interlaminated with bands of gneiss, similar to those now seen forming the beds of the sea bordering Australia, the coast of South and Central America, &c., where marine productions analogous to the most ancient fossil remains now flourish and become imbedded in the exposed soft surface of the primary fundamental base. Therefore we need not be surprised at finding such remains in the upper edges of the crystalline bands of the primary limestone in Canada or any other part of the world.

At the last Meeting of the British Association, in a discussion with reference to *gneiss* rocks, observations were made by professors of geology showing most conclusively that they did not know the difference between the rock called "gneiss" and a laminated sedimentary bed of "micaceous sandstone." It is truly most unfortunate to the students of geology and to the progress of the science that the vertical structure referred to, and the general character and conditions of the primary series, are not better known and explained by those who profess to teach geology.

The Earth's Orbit.

In a note, page 130, reference is made to the apparent cause of the variable diameter of the sun, on which Kepler founded his theory of the eccentricity of the orbit.

For instance, at Greenwich, say latitude 51° 28′ 38″ north, the angular diameters appear in

				Sun's diameter.	
June . . .	∠61°	58′	30″	31′	.30″
September . .	38	31	22	31	58
December . .	15	3	50	32	36

Kepler supposed that the sun appeared *in all parts of the earth* less in June than in December, and arrived at the conclusion that the earth was nearer to the sun in the month of December than in June, and thereon established his theory of the eccentricity of the orbit.

Numerous observations made during many years in the equatorial zone and in the southern hemisphere have proved that the variable diameter of the sun is caused by our atmospheric lens, and is not the effect of varying distances.

At Melbourne, latitude 38° south, the following measurements were obtained:—

		Sun's diameter.
June	∠ 28° 22′	32′ 20″
September . . .	52 0	31 40
December . . .	75 27	31 0

In 51° latitude south, near the Straits of Magellan—

June	15° 50′	32′ 30″

Within the tropics, all the year round, the diameter of the sun in the *zenith* is about 30′ 35″, and from 32′ 50″ to 33′ 0″ in rising and setting. Hence it follows that the assumed ellipticity of the earth's orbit is founded on an optical illusion, which misled Kepler when the effect of refraction was but little understood.

The laws of refraction are not yet ascertained with sufficient accuracy to be depended upon in all latitudes and altitudes; and this uncertainty has not only caused a misconception as regards the variation in the sun's diameter, but also affects and vitiates many of what have hitherto been regarded as fundamental data of physical astronomy.

The Moon's Atmosphere.

In page 129 it is remarked that the supposed *non*-existence of a lunar atmosphere could not be sustained (according to the laws of optics) on the ground that no refraction was observed during the occultations of the stars. It is further demonstrated, and generally admitted, that the *entire half of the spherical surface* of the globe could not be illuminated had it not been for the atmosphere refracting the rays of the sun towards the external margin. The moon, when in quadrature, is seen *half illuminated.* How could half *the spherical surface of the moon* be illuminated with such bright light, even to the "terminator," by means of the direct rays of the sun in the absence of a lunar atmosphere? We quite agree with the remark of Mr. De la Rue, the President of the Astronomical Society, that "it was difficult to conceive any chemical formation of matter in the absence of an atmosphere."

We have no physical proofs of the non-existence of a lunar atmosphere; on the contrary, the illumination of half of her surface indicates the probable existence of a lunar atmosphere and refraction.

The alleged Rotation of the Moon. (Page 129.)

When the author incidentally remarked in writing the first edition, upwards of twenty-six years ago, that the alleged rotation of the moon was a mistake, and that our satellite (with reference to the earth) had only a revolving motion, he little thought at that time that such a simple dynamical question would have continued such a source of dispute to this day. Since then Mr. H. Perigal, Jun., has written many able pamphlets on the subject, and has fully and most clearly demonstrated the fallacy of the alleged rotation of the moon. The misconception, however, appears to be so deeply rooted as not to be easily eradicated; and as mankind in general take no trouble about exercising their own judgment in scientific matters, but prefer adopting what is prescribed and prepared for them, the question must be left to be corrected by time and scientific changes. Mr. Perigal has given the following definitions of *Revolution* and *Rotation*:—

"*Revolution* and *Rotation* are the two ways of turning round. When a body turns round a centre, or axis, it revolves; if it turns round its own centre, or axis, it rotates: rotation is the limit of revolution, and revolution is extended rotation.

"Thus rotation denotes a circular movement round an *interior* centre or axis: while revolution signifies a circular movement round an *exterior* centre or axis, more or less distant from the revolving body.

"By simply rotating, a body does not move away from the space it occupies when at rest: but in revolving a body traverses a ring of space of which it occupies a small portion when at rest.

"The movement of a planet through space is orbital revolution. Its spinning movement, round an imaginary axis within itself, is axial rotation. For instance, the earth rotates on its axis once a day, and revolves round the sun once a year." The moon has no spinning motion, and presents constantly the same face towards the centre of revolution. How, then, can she rotate? Kepler justly maintained that "the moon was not endowed with rotation." It is difficult to conceive how such an idea originated, especially among men who had studied the laws of dynamics and comprehended the terms employed to distinguish rotation from revolution. The late Mr. Jellinger Symons revived the question in letters inserted in the 'Times' in 1856, but only to be abused and ridiculed. The replies of his opponents showed the weakness of their cause and the sad effect of routine training and cramming; they abstained from dynamical definitions, and found it more convenient to abuse him and withold their names than to venture on dynamical arguments*.

The supposed predominance of an Atmosphere highly charged with Carbonic Acid, in the regions where the Carboniferous Plants flourished.

This idea originated with M. Brongniart, and has been accepted as a quasi-fact to this day, as will be seen on reference to geological works. The author, however, has maintained, and proved from long residence in regions where luxuriant vegetation (palms, fern trees, &c.) flourished, that an atmosphere charged with carbonic acid was not necessary for their growth. The author has been the only geologist who has opposed M. Brongniart's views, as far as we can judge from geological works. (See page 145.)

Numerous experiments have been made on the growth of plants in an atmosphere charged with carbonic acid; and the results have been found unfavourable, as might have been anticipated.

An equable and moist climate, with rich carbonaceous soil, are the conditions required to nourish such plants as those found in the coal-formations. The reviewer of M. Figuier's 'World before the Deluge,' in the 'Times' of last Nov. 22nd, appears to entertain many of the views which have been long maintained in this work, but opposed by geologists. The reviewer not only repudiates the igneous theory with all its absurdities, but also makes the following observation on M. Brongniart's carbonic-acid theory, which are in accordance with the arguments brought forward at page 145. He remarks:—

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* The author, in his letter to the 'Times' (April 1856), in support of Mr. Symons, gave the following definition:—"Rotation means the act of turning round on an axis situated *within the body* spinning round; and Revolution means the act of turning round a centre—in a circle—the axis being placed *beyond the body*, in the centre of its circular path." A body cannot revolve without turning on its *revolving centre* once in each revolution. It is necessarily a *revolving* effect and not rotation. Such is the motion of the moon.

"It is now the universal opinion among botanists that the phenomena presented by the coal-plants indicate rather a warm, moist, and equable climate, without any great cold in its winter, than tropical condition with deluge of rain.

"The living representatives of the coal-plants are not to be found in the tropics, but rather in such conditions as are presented now in New Zealand, where a climate obtains such as we have indicated. *It is unnecessary to invoke the aid of an atmosphere of carbonic acid to account for the richness of vegetation.*" .... "The idea that terrestrial heat can have influenced climate throughout long geological periods, has been shown to be entirely untenable." (See pages 144 and 157; and with regard to alterations in climate, see page 118.)

Theory of Projectiles, &c. (Page 178.)

The observations made on this subject remain the same as they were originally written. No satisfactory explanation has as yet been given to account for the attempts which have been made in favour of the supposition that a *solid body* could continue to revolve round a centre and be retained suspended in a circular orbit without any support but that of a projectile action! How *rectangular* parallelograms came to be applied to compounds with *central* forces, and chords made equivalent to arcs, is indeed difficult to conceive. Again, to have accepted such assumptions as the fundamental laws of physical science simply on the credit of Halley is truly marvellous! Dr. Whewell remarks, in his 'History of Astronomy,' that before Newton's mathematical demonstrations "were published, they were proclaimed by Halley as something of transcendant value .... Some of the leading members of the Royal Society embraced the system immediately and zealously solely .... on the credit of their mathematical friends. . . . . Even Newton's countrymen did not produce anything which showed that they had mastered, or understood, the Newtonian investigation . . . . They abandoned the mental effort necessary for geometrical demonstrations, and gave the subject over to the operation of *algebraical reasoning and symbols, without dwelling upon their meaning*"!

These and other cognate subjects have been recently most ably treated in a well-written work*.

The various fallacies in physical astronomy are so clearly exposed and geometrically tested by parallelograms, and so elegantly described and temperately criticised, that none of the professors of the established physical theory have had the courage to attempt to confute the author on strictly scientific grounds. Mr. Reddie, by simple demonstrations, obtained by the application of even the accepted laws of motion and the parallelograms of forces and velocities, exhibits, in a most convincing manner, results which are totally incompatible with the lemmas in the first section of the *Principia*. Indeed the first book refutes mathematically the so-called demonstrations of the foundation propositions upon which the present physical theory was based. The public are willing to be guided by the leading scientific men, and are at all times ready to respect them; but they now begin to think that scientific theories require revision and many corrections, not alone as regards the constitution of the sun and its distance from the earth, which astronomers acknowledge require reconsideration, but also in many other respects. Therefore, in the present matter of fact age, the public consider that they have a right to expect satisfactory explanations of all important scientific questions in dispute; consequently such a book should be properly *answered*, and not be evaded, ignored, and denounced, as such a mode of treating important scientific subjects only tends to furnish additional proofs of the weakness and the unsatisfactory state of the established theories. We strongly recommend Mr. Reddie's work to the consideration of geometricians who may feel an interest in investigating the *fundamental truths* of science. Many eminent men are beginning to confess that a better class of elementary authoritative works is now required for the guidance of young students in natural philosophy, who are perplexed with the unsatisfactory state of mathematical and physical science as applied to astronomy and the laws of projectiles. No man who professes to share in the enlightenment and intelligence of the age ought to be content, for instance, with believing that, "if he flings a stone obliquely upwards into the air, *it will descend at the same angle as when it quitted his hand,*" without testing its accuracy. "It is on such an argument that Newton is understood to have rested his law of gravitation"*. Every fact of natural science is as much a fact now as it was in the days of Newton; and if we find that a projected body *does not return to the earth at the same angle as it was thrown up,* it is evident that the above statement cannot be accepted by those who are desirous to arrive at the truth and who feel an interest in the progress of science.

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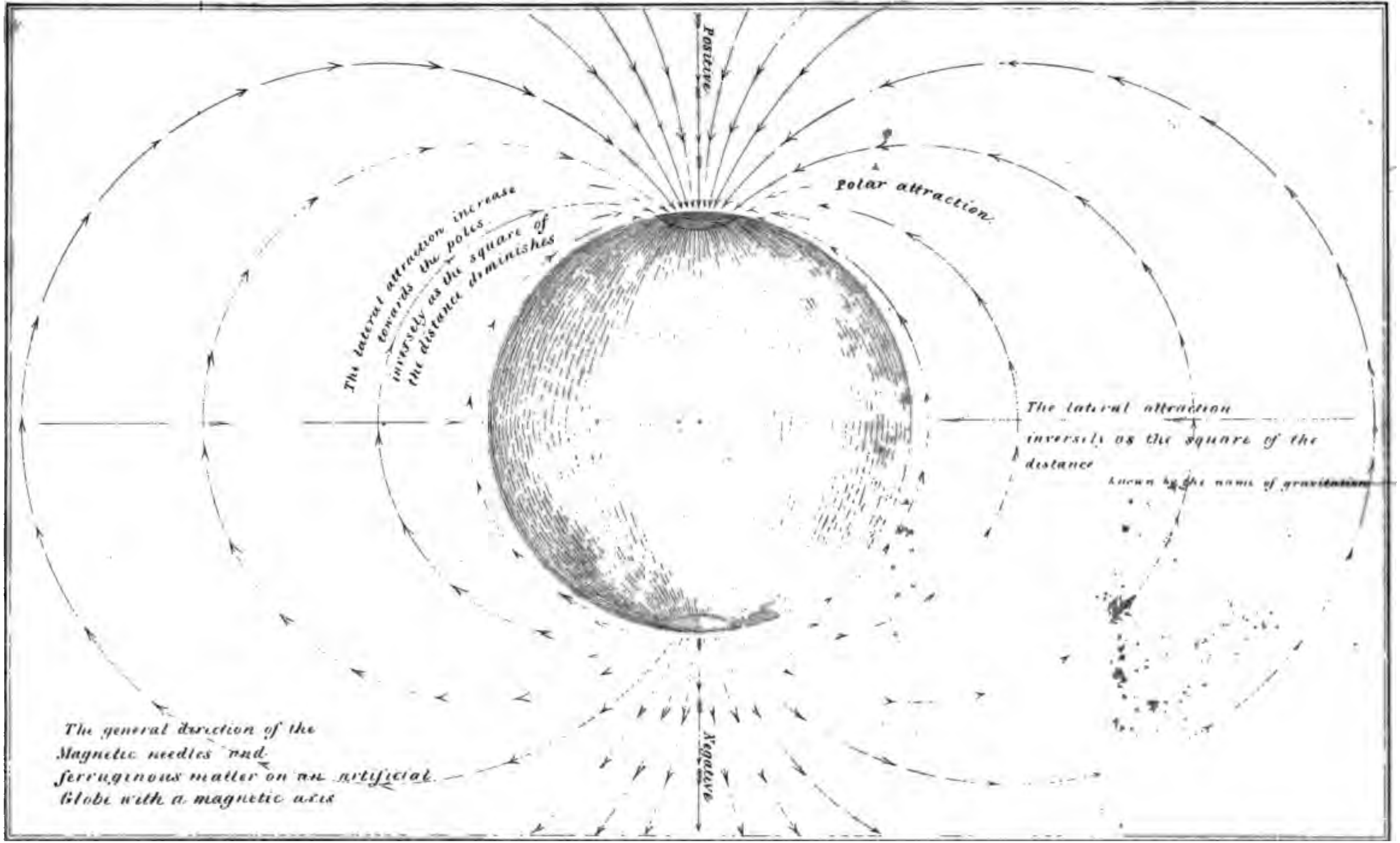
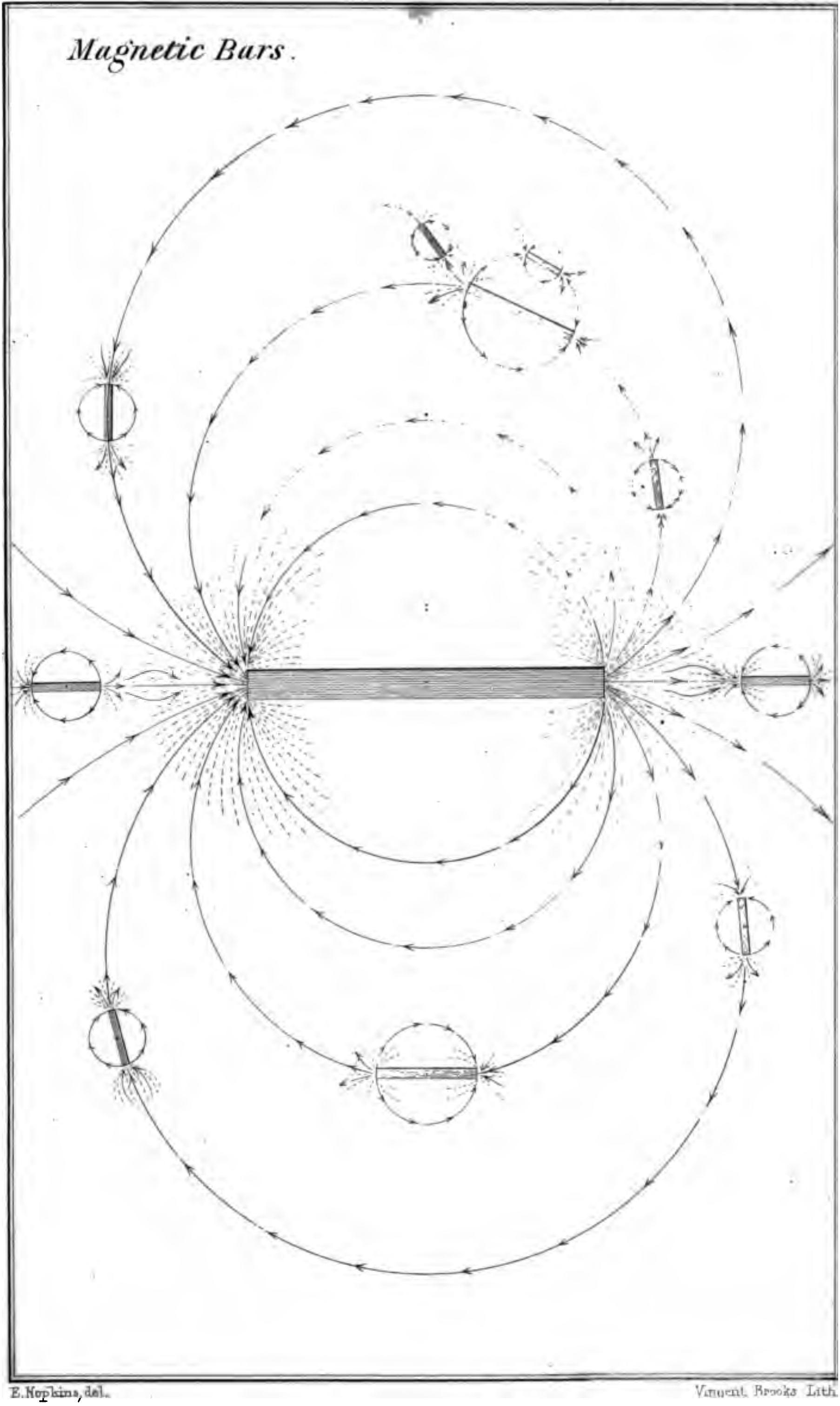
* Current Physical Astronomy critically examined and confuted, in three Books:—I. Vis Inertiæ Victa; II. The Mechanics of the Heavens; III. Victoria Toto Cœlo. By James Reddie, Esq., Hon. Mem. Dial. Soc. Edin. Univ. Charles Griffin and Co.; Robert Hardwicke, Piccadilly, London.

* Herschel's Astronomy. See quotation, p. 176.

Pl. 1.


Positive
Polar attraction
The lateral attraction increase towards the poles inversely as the square of the distance diminishes
The lateral attraction inversely as the square of the distance
known by the name of gravitation
Negative
The general direction of the Magnetic needles and ferruginous matter on an artificial Globe with a magnetic axis

Pl. II.



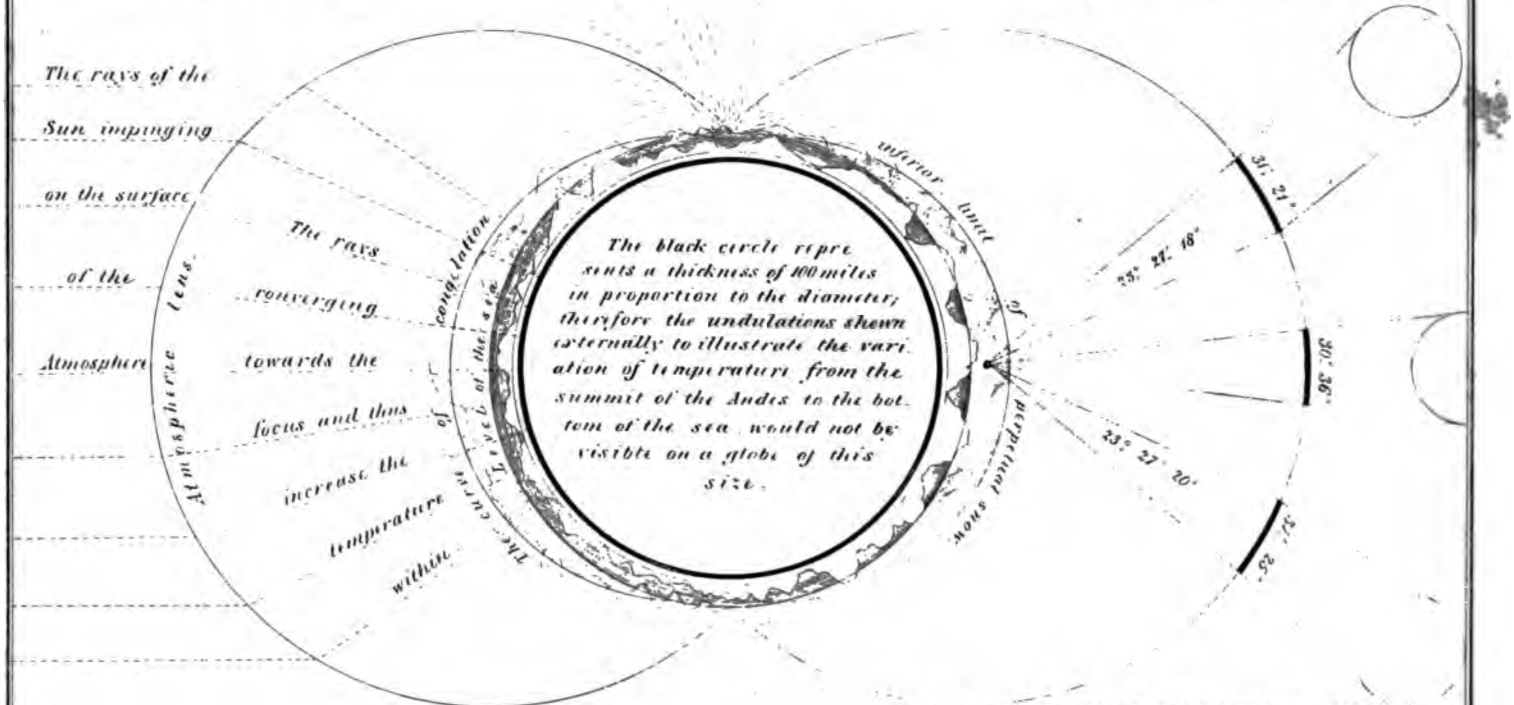
Magnetic Bars.

E. Hopkins, del.

Vincent Brooks Lith.

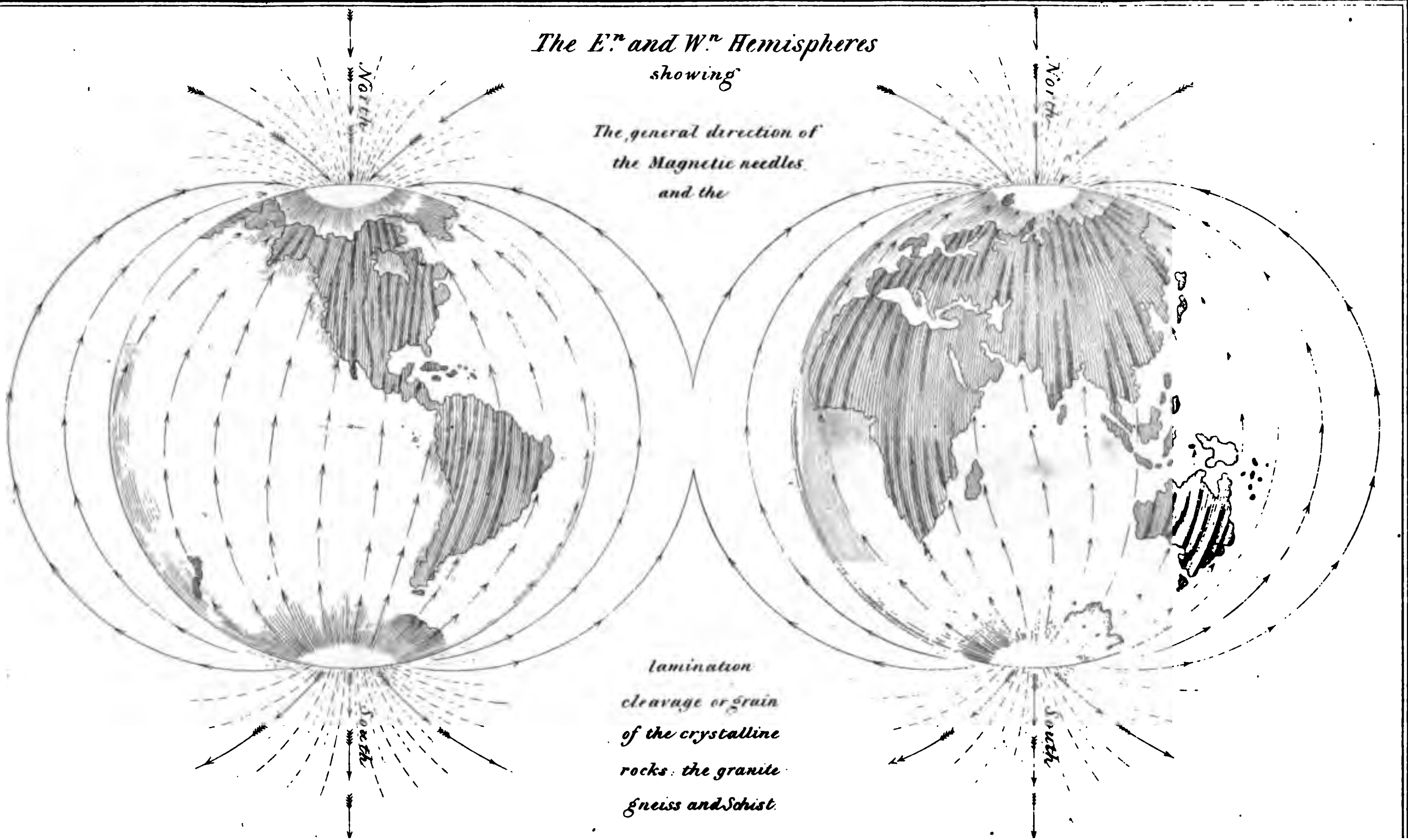
Pl. III.

The effect of the Atmospheric lens.



The black circle represents a thickness of 100 miles in proportion to the diameter; therefore the undulations shewn externally to illustrate the variation of temperature from the summit of the Andes to the bottom of the sea would not be visible on a globe of this size.

The above represents the refraction of the suns rays and the apparent augmentation of the diameter according to observations made near the equator from the S. tropic to the N. tropic

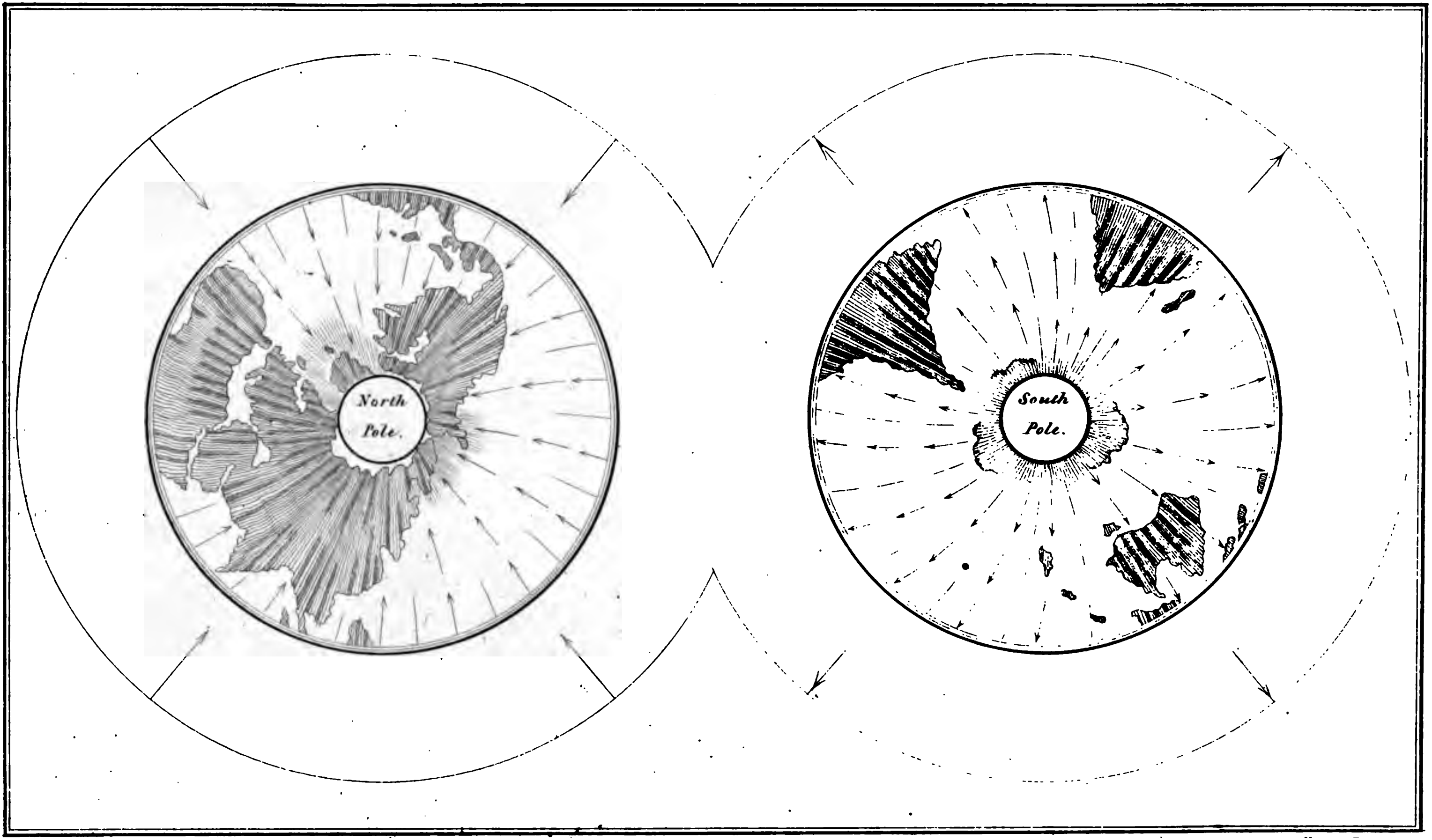


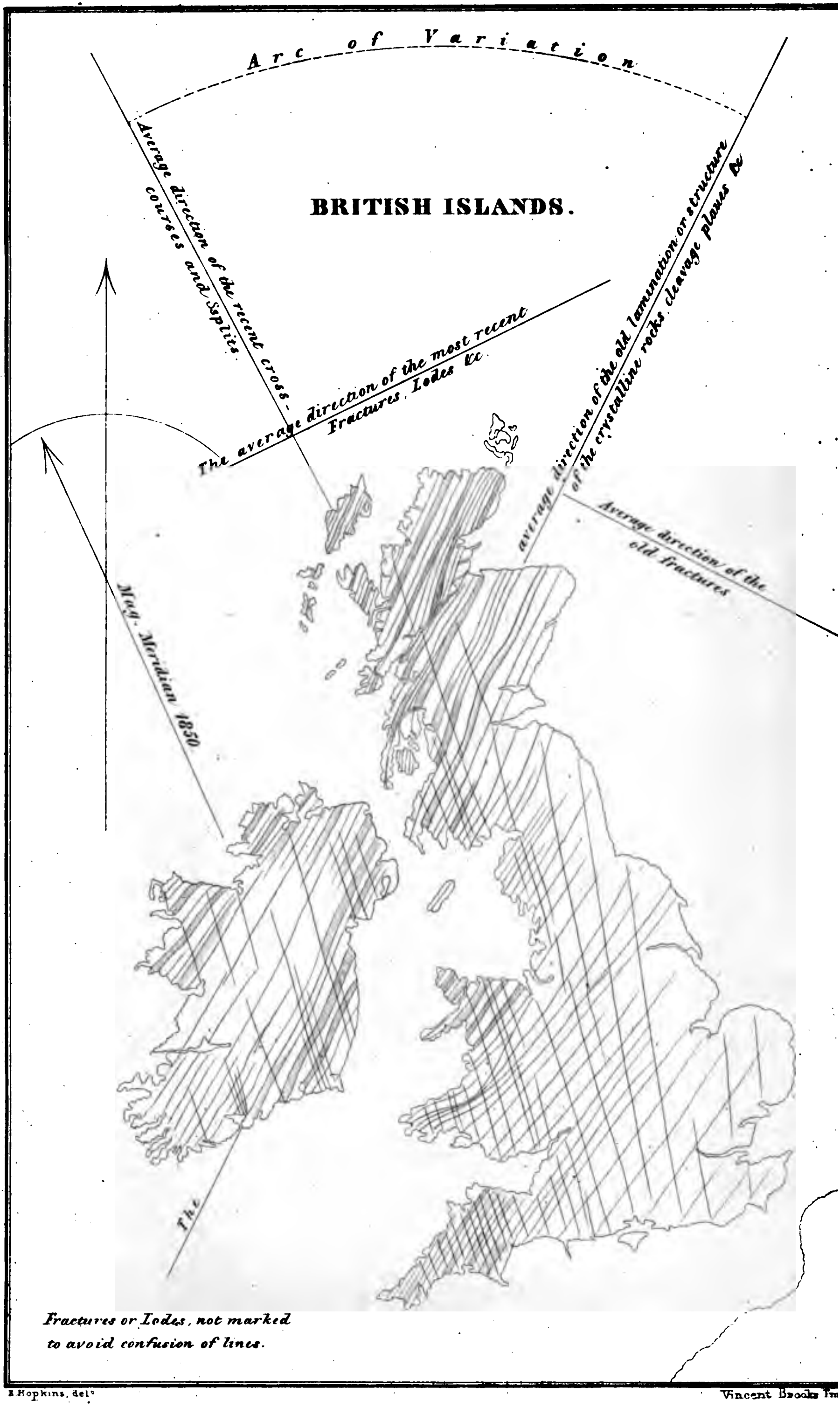
The Eⁿ. and Wⁿ. Hemispheres
showing

The general direction of
the Magnetic needles
and the

lamination
cleavage or grain
of the crystalline
rocks: the granite
gneiss and Schist.

Pl. V.





BRITISH ISLANDS.

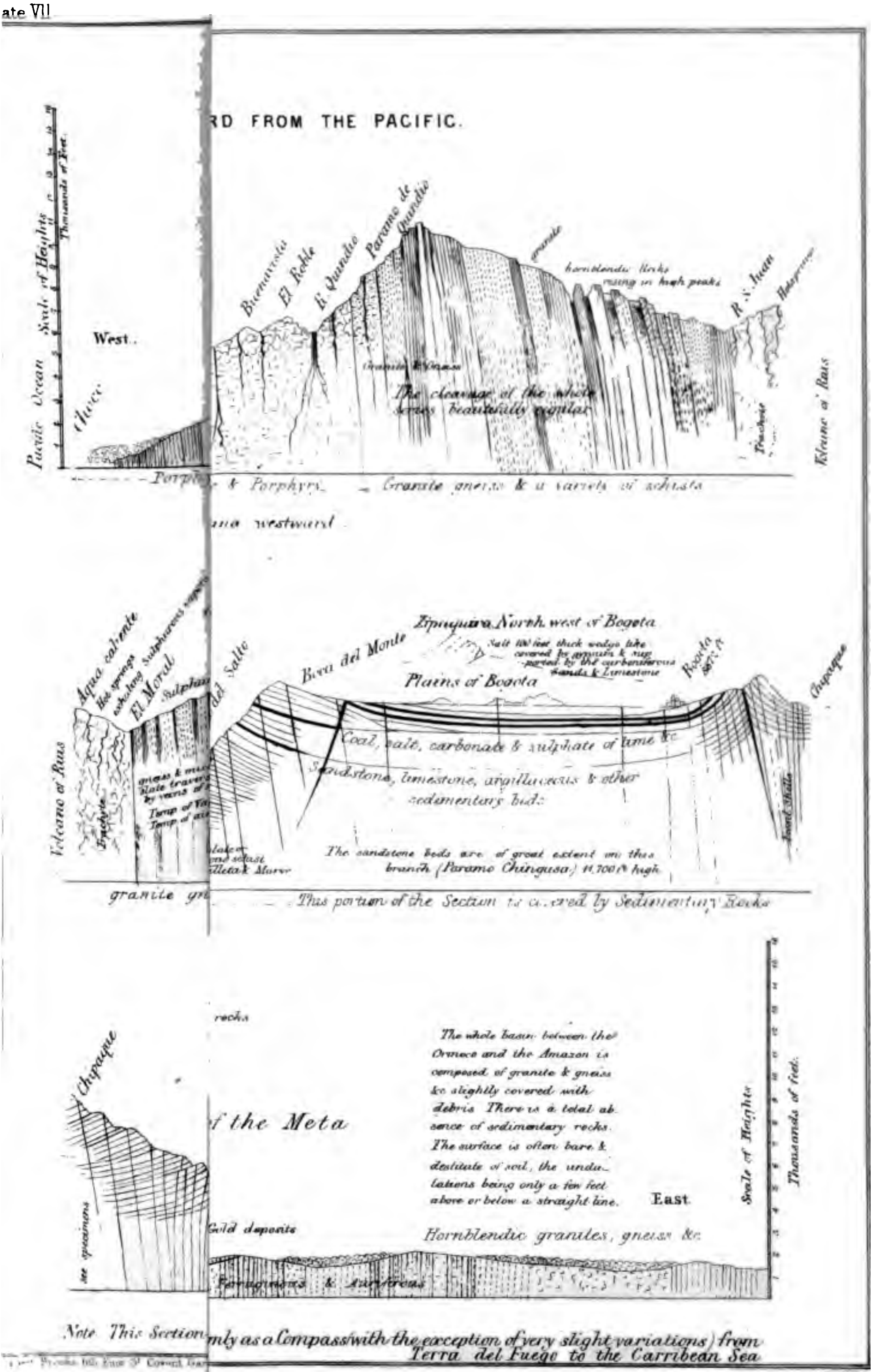
Arc of Variation
Average direction of the recent cross-courses and ssplits.
The average direction of the most recent Fractures, Lodes &c
average direction of the old lamination or structure of the crystalline rocks, cleavage planes &c
Average direction of the old fractures
Mag. Meridian 1850
The

Fractures or Lodes, not marked to avoid confusion of lines.

E. Hopkins, delt.

Vincent Brooks Im

ate VII



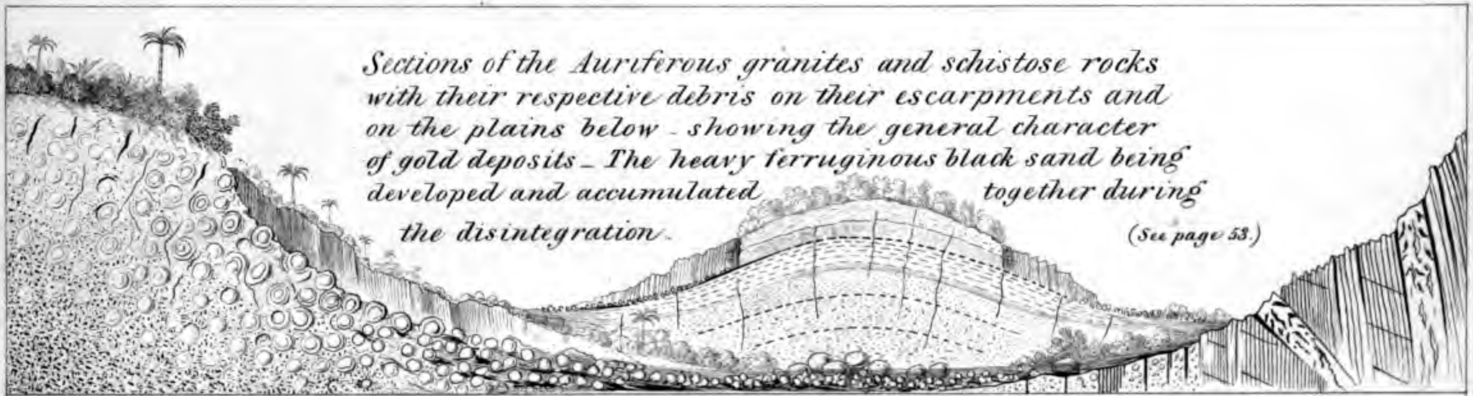
RD FROM THE PACIFIC.

Pacific Ocean
Scale of Heights
Thousands of Feet
West.
Choco
Buenavista
El Roble
E. Quindio
Paramo de Quindio
granite
hornblendic Rocks rising in high peaks
R. S. Juan
Granite & Gneiss
The cleavage of the whole series beautifully regular
Trachyte
Volcano of Ruis
Porph & Porphyry
Granite gneiss & a variety of schists
ana westward
Agua caliente
Hot springs exhaling Sulphureous vapours
El Moral
Sulphur
del Salto
Volcano of Ruis
Trachyte
gneiss & mica slate traversed by veins of
Temp of Va
Temp. of air
slate & schist
Mariquita
Boca del Monte
Zipaquira North west of Bogota
Salt 100 feet thick wedge like covered by gypsum & supported by the carboniferous Sands & Limestone
Plains of Bogota
Bogota
Chipaque
Coal, salt, carbonate & sulphate of lime &c
Sandstone, limestone, argillaceous & other sedimentary beds
Fossil Shells
The sandstone beds are of great extent on this branch (Paramo Chingusa) 14,700 ft high
granite gn
This portion of the Section is covered by Sedimentary Rocks
Chipaque
see specimens
rocks
of the Meta
The whole basin between the Orinoco and the Amazon is composed of granite & gneiss &c slightly covered with debris There is a total absence of sedimentary rocks. The surface is often bare & destitute of soil, the undulations being only a few feet above or below a straight line.
East.
Scale of Heights
Thousands of feet.
Gold deposits
Hornblendic granites, gneiss &c
Ferruginous & Auriferous

Note This Section nly as a Compass(with the exception of very slight variations) from Terra del Fuego to the Carribean Sea

E.H. del

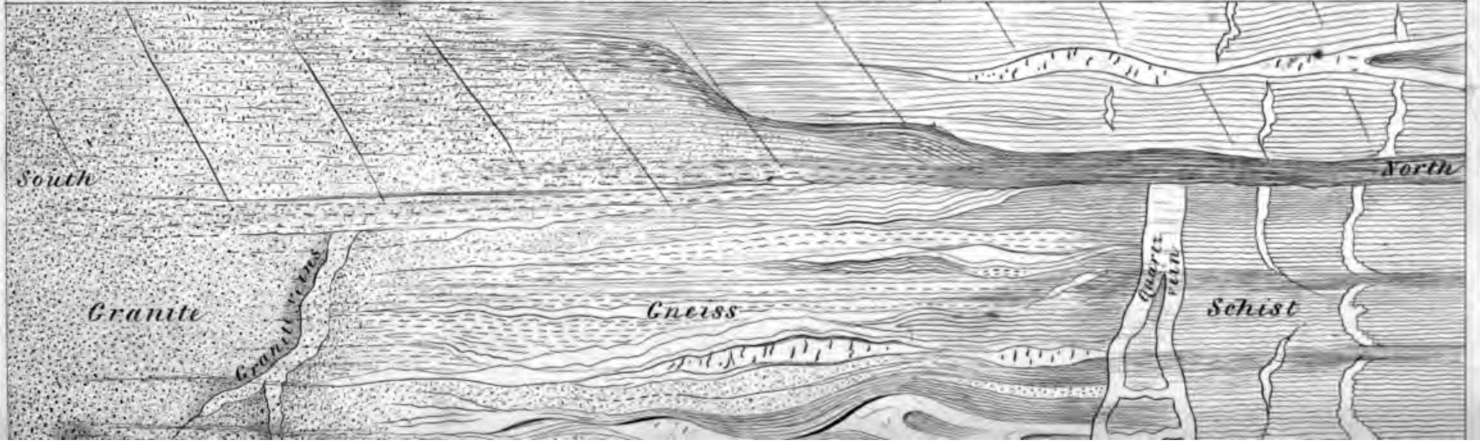
Pl. VIII.



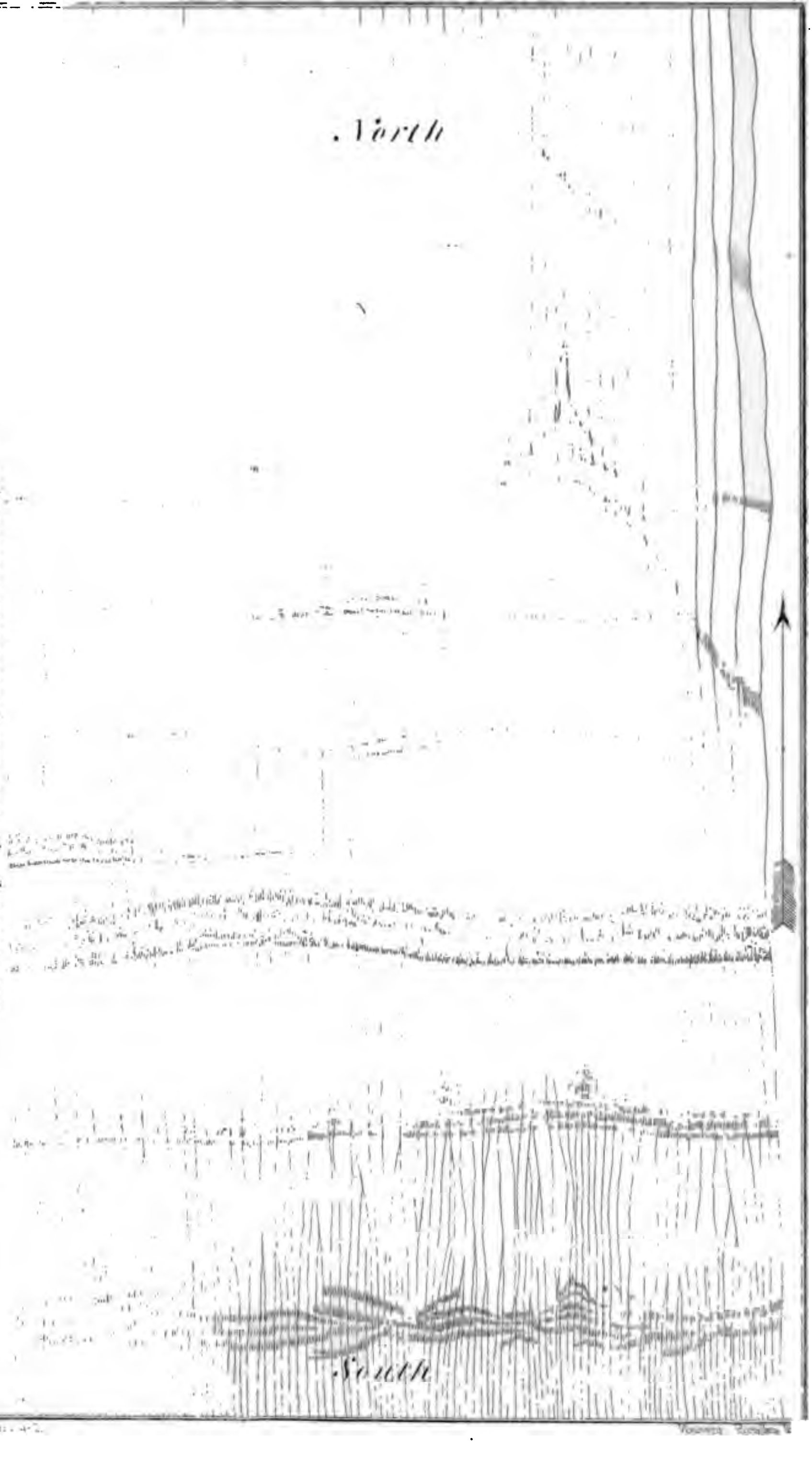
Sections of the Auriferous granites and schistose rocks with their respective debris on their escarpments and on the plains below _ showing the general character of gold deposits _ The heavy ferruginous black sand being developed and accumulated together during the disintegration.

(See page 53.)

The Transition of Granite into Gneiss and Schist in a N^ly direction.



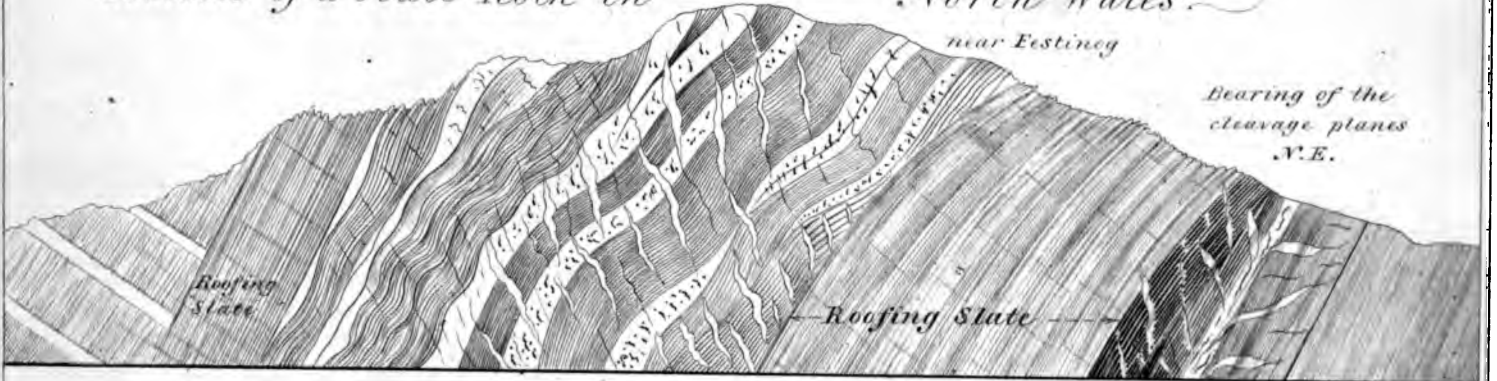
Pl. IX.



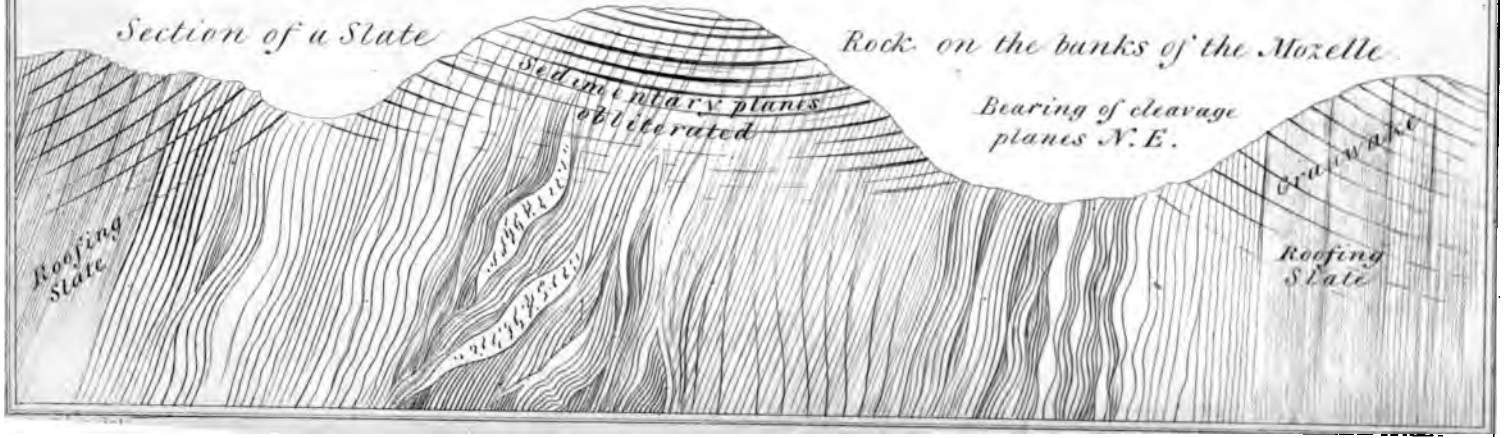
Plan of a metalliferous formation in the ANDES showing the Old E & W veins undergoing alteration &c. & new cleavage of siliceous substances.

Section of a slate Rock in North Wales.

near Festinog



Section of a Slate Rock on the banks of the Mozelle



Pl.XI.

Fig. 1.

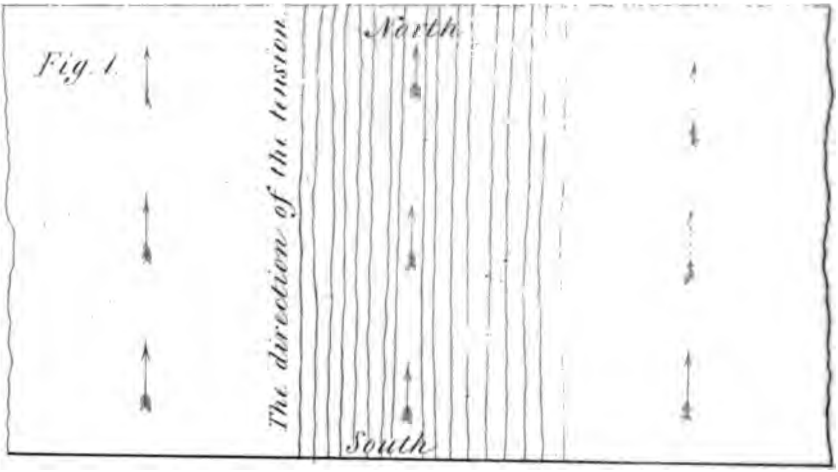


Fig. 2.

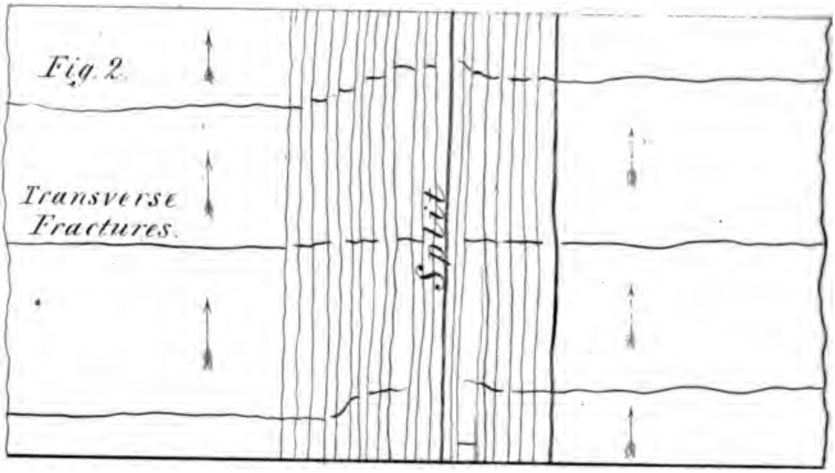
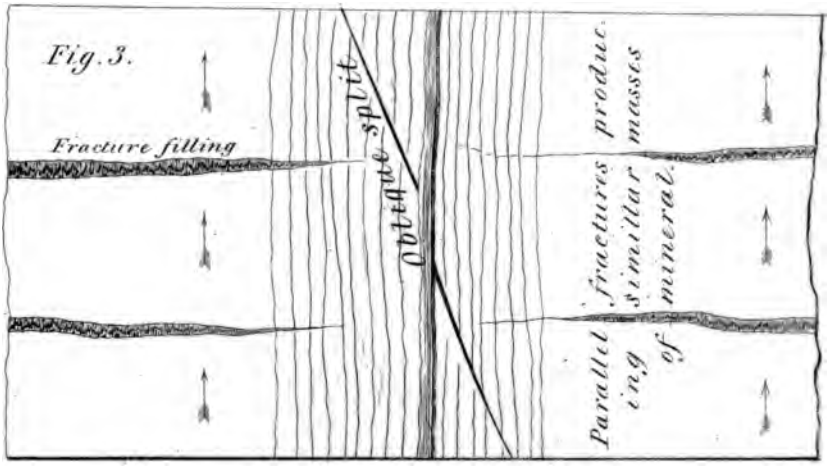
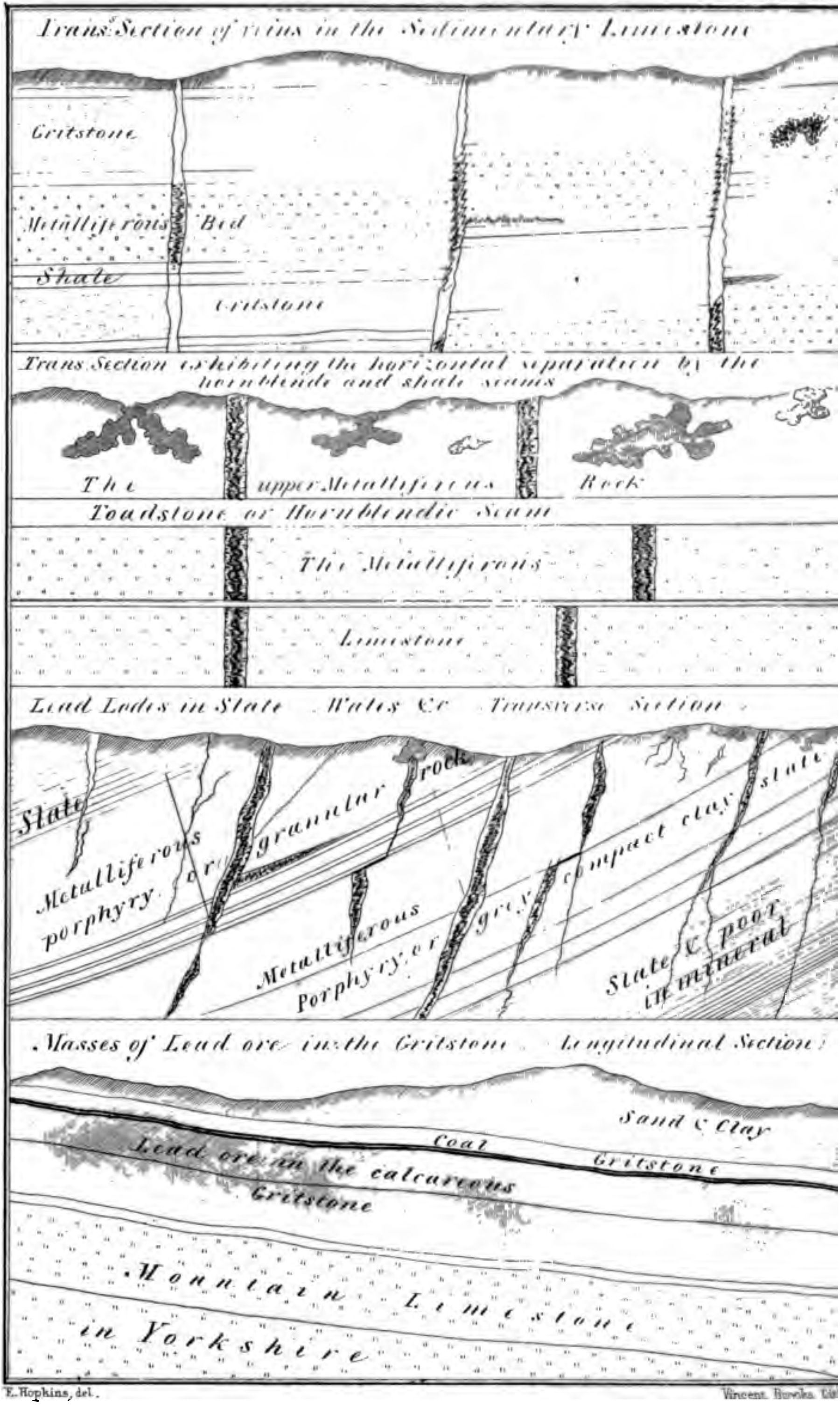


Fig. 3.



F. Hopkins del.
Vincent Brooks L.

X.I

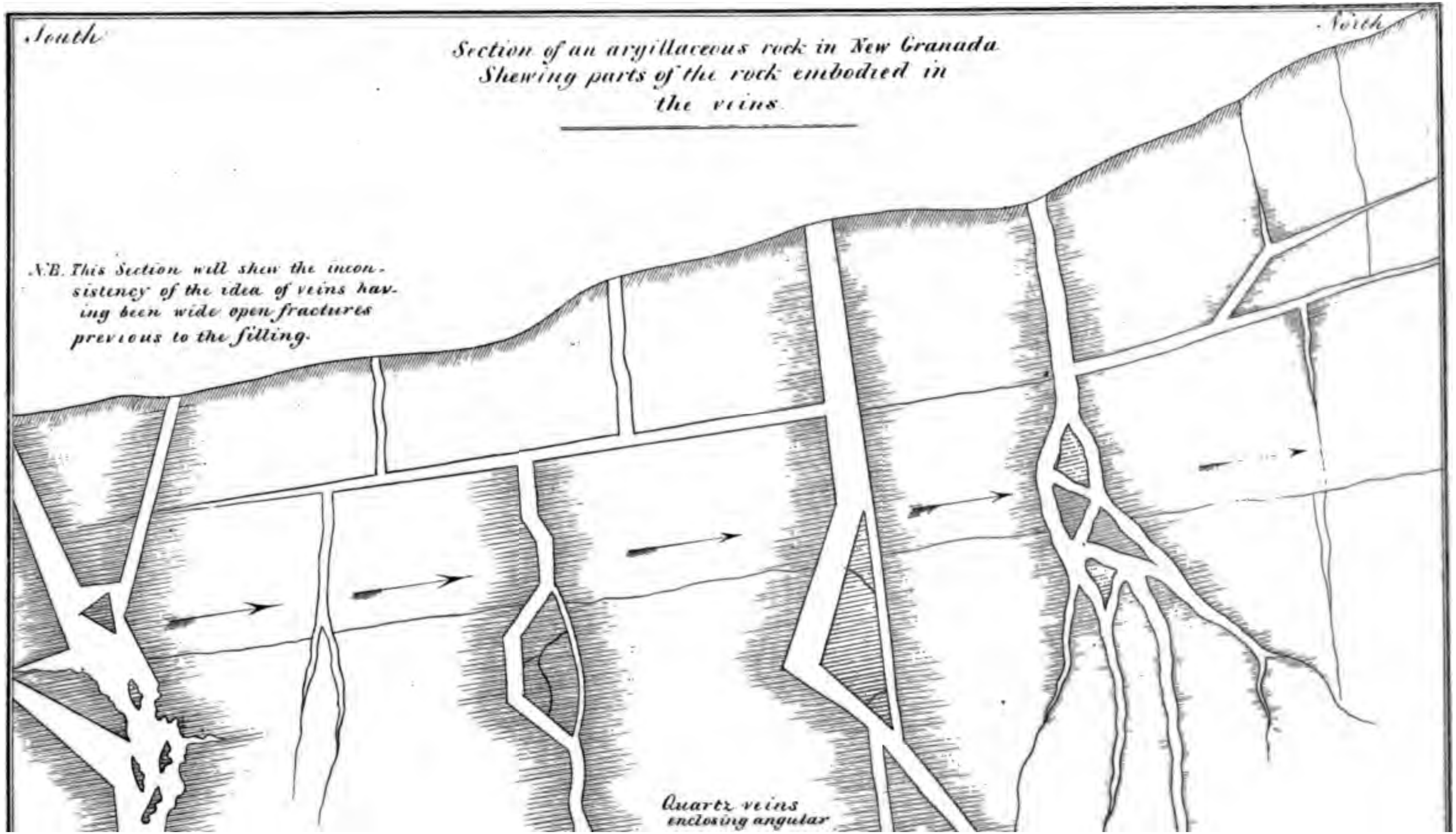

Trans.l Section of veins in the Sedimentary Limestone
Gritstone
Metalliferous Bed
Shale
Gritstone
Trans. Section exhibiting the horizontal separation by the hornblende and shale seams
The upper Metalliferous Rock
Toadstone or Hornblendic Seam
The Metalliferous
Limestone
Lead Lodes in Slate Wales &c Transverse Section
Slate
Metalliferous porphyry or granular rock
Metalliferous Porphyry or grey compact clay slate
Slate & poor in mineral
Masses of Lead ore in the Gritstone Longitudinal Section
Sand & Clay
Coal
Gritstone
Lead ore in the calcareous Gritstone
Mountain Limestone in Yorkshire

E. Hopkins, del.

Vincent Brooks Lit

Pl. XIII.

Section of an argillaceous rock in New Granada Shewing parts of the rock embodied in the veins



N.B. This Section will shew the inconsistency of the idea of veins having been wide open fractures previous to the filling.

Fig. 1.

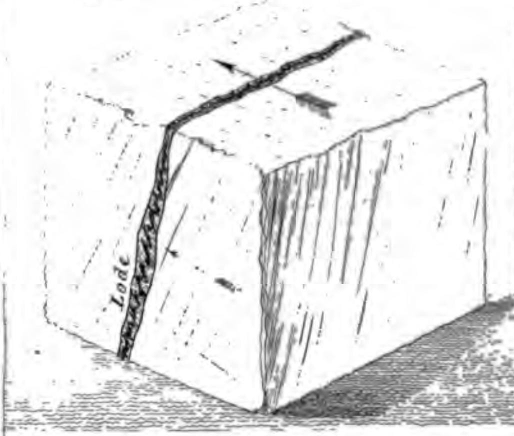


Fig. 2.

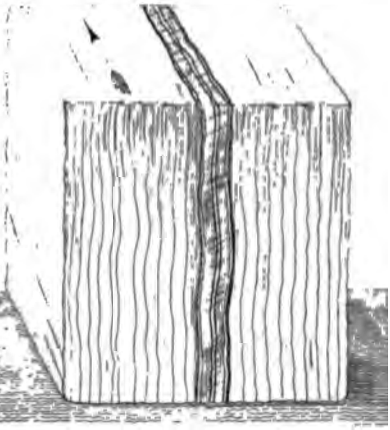


Fig. 3.

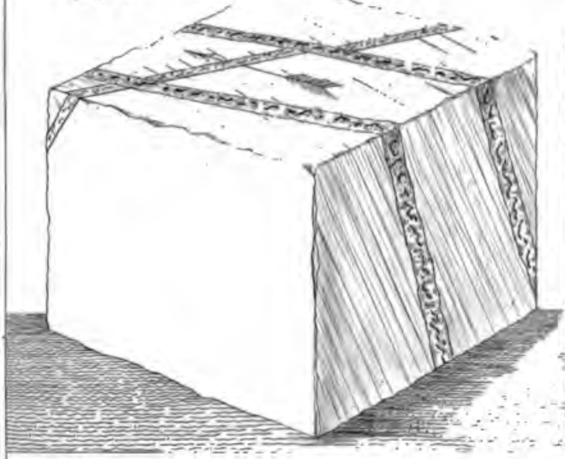


Fig. 4.

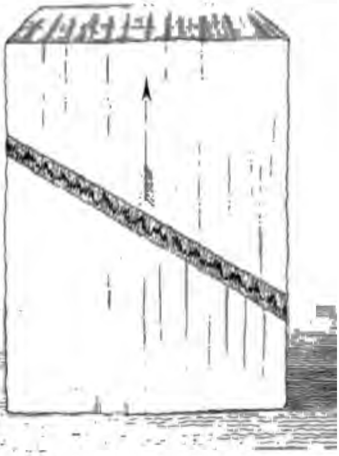
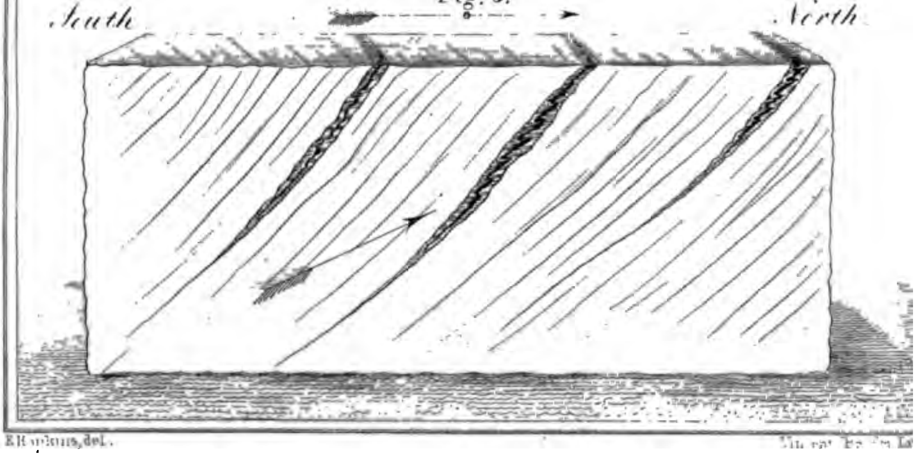
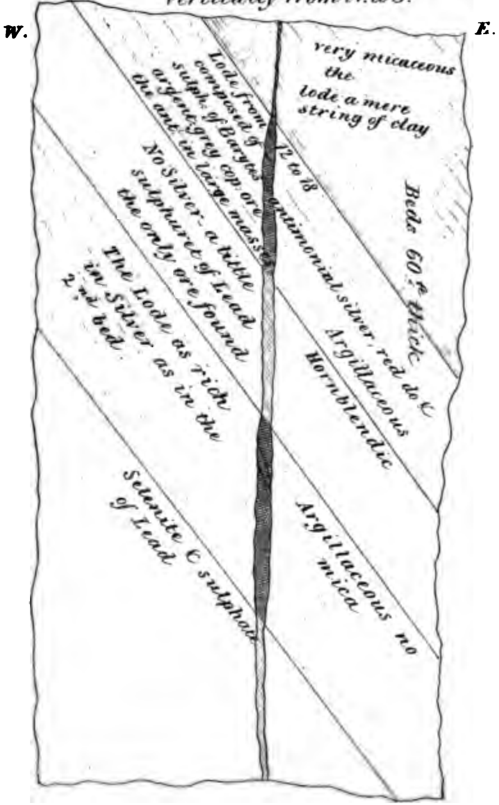


Fig. 5.

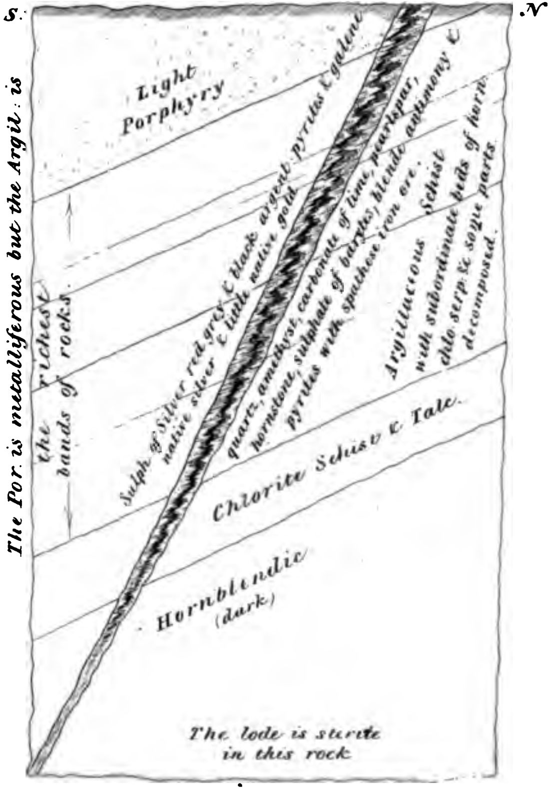


E. Hopkins, del.

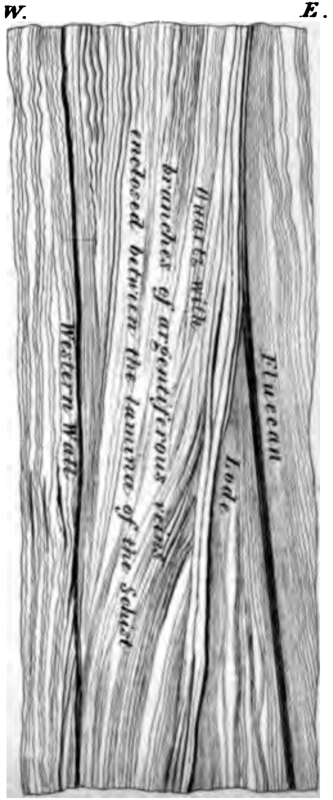
Wenzel Lode at Fürstenburg.
vertically from N. to S.



The general position of the
Veta Grande & Valenciana Mines.

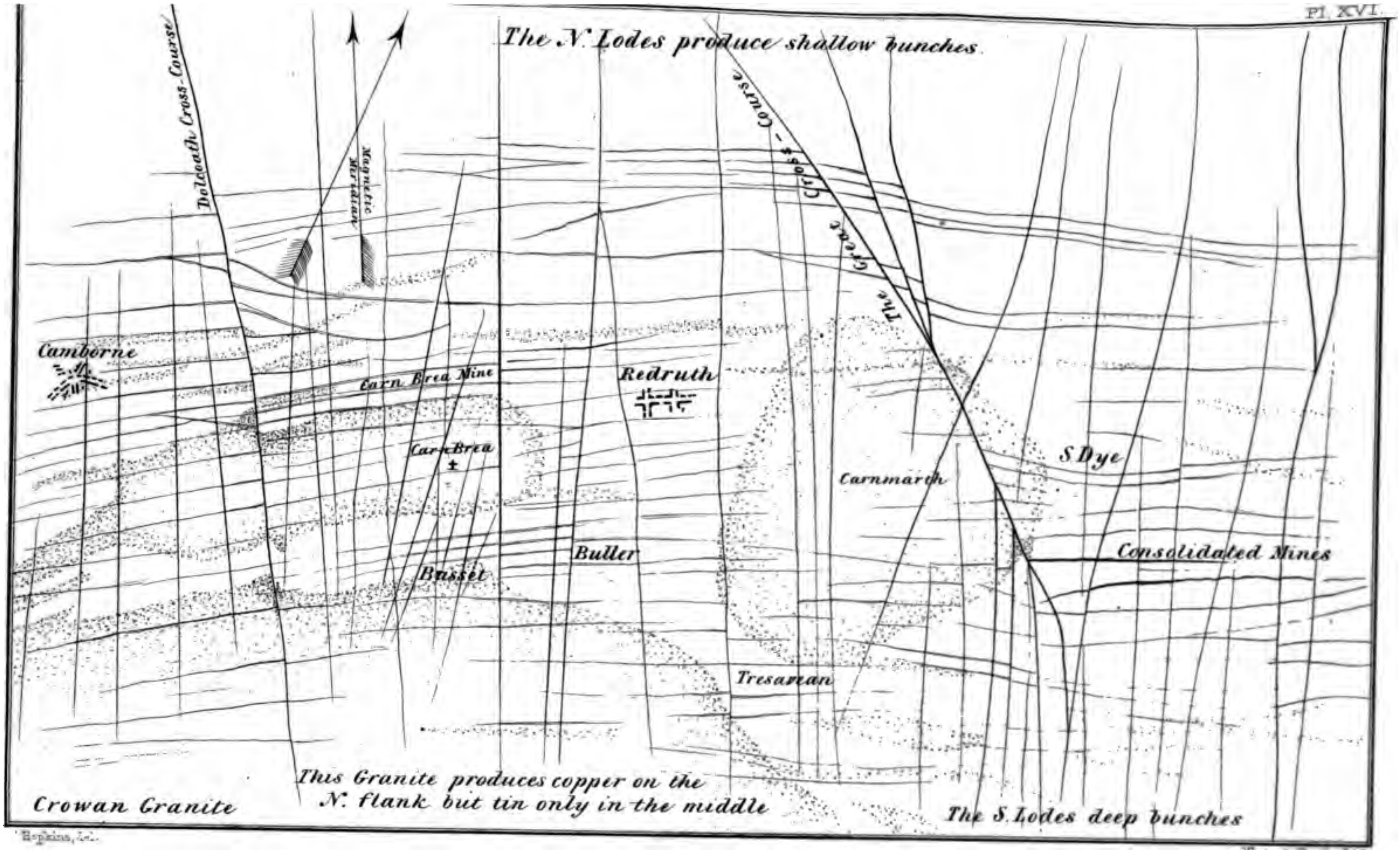

S.
N.
The Por. is metalliferous but the Argil. is
the richest
bands of rocks
Light
Porphyry
Sulph. of Silver red grey & black argent. pyrites & galena
native silver & little native gold
quartz, amethyst, carbonate of lime, pearlspar,
hornstone, sulphate of barytes, blende antimony &
pyrites with spathose iron ore.
Argillaceous Schist
with subordinate beds of horn
chlo. serp. & some parts
decomposed.
Chlorite Schist & Talc.
Hornblendic
(dark)
The lode is sterile
in this rock

St. Ana Mine. N. Granada.

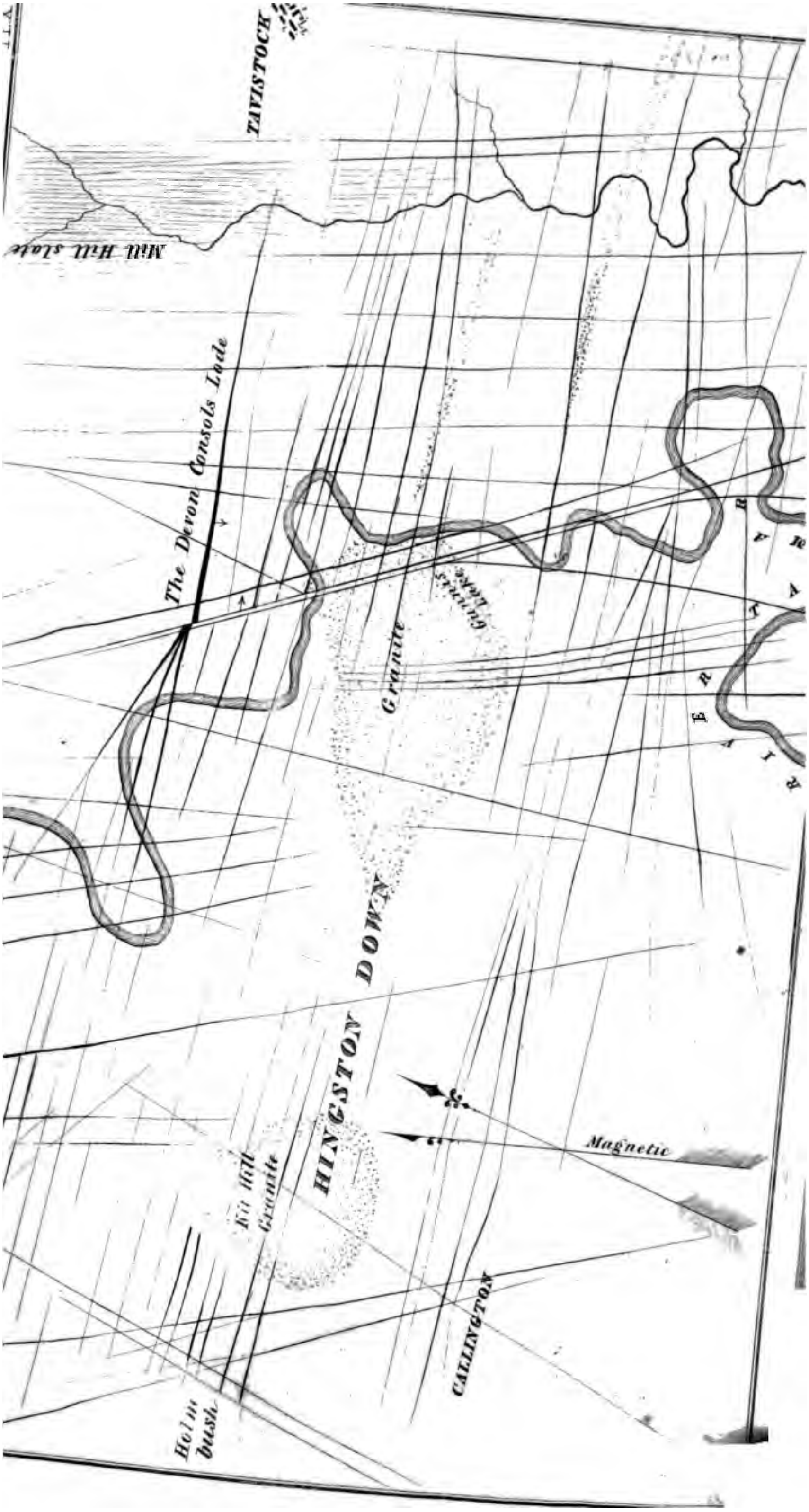

W.
E.
Western Wall
Quartz with
branches of argentiferous veins
enclosed between the lamina of the Schist
Fluecan
Lode

Vincent Brooks Lith.

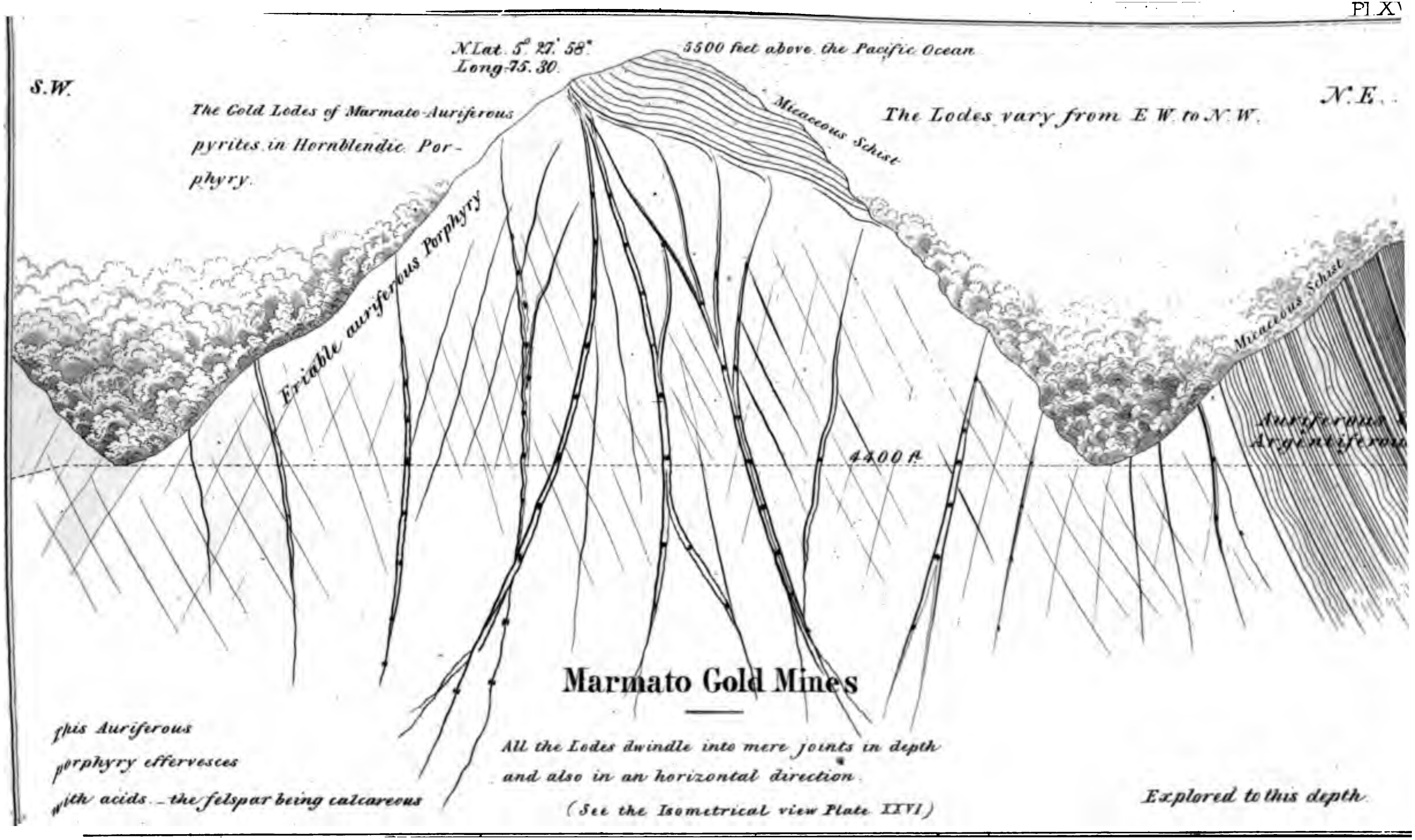
Pl. XVI.



Hopkins, Lit.


TAVISTOCK
Mill Hill slate
The Devon Consols Lode
Granite
Gunnis Lake
RIVER TAMAR
HINGSTON DOWN
Kit Hill Granite
Magnetic
Holm bush
CALLINGTON

Pl. X



The Gold Lodes of Marmato-Auriferous pyrites in Hornblendic Porphyry.

The Lodes vary from E. W. to N. W.

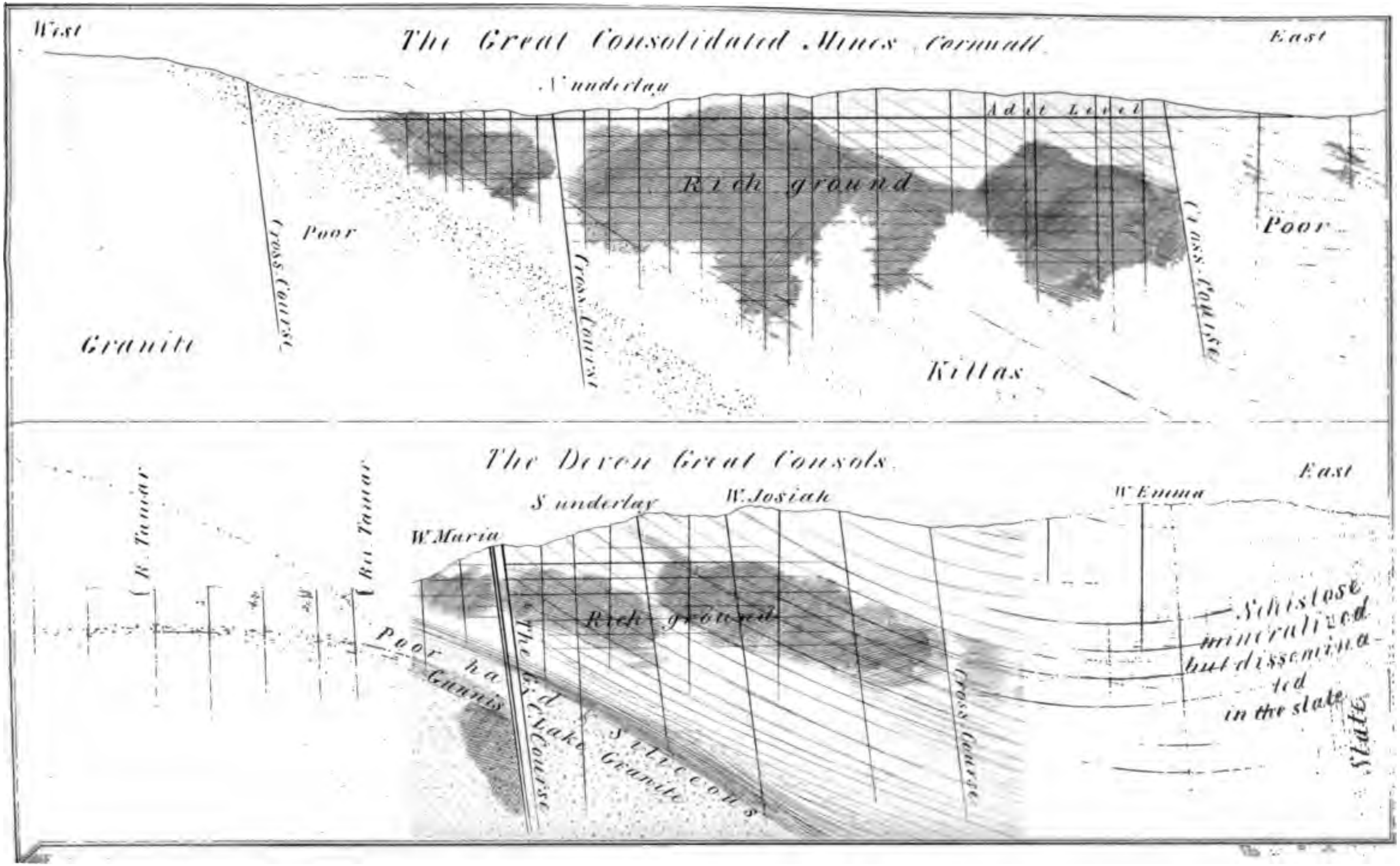
Marmato Gold Mines

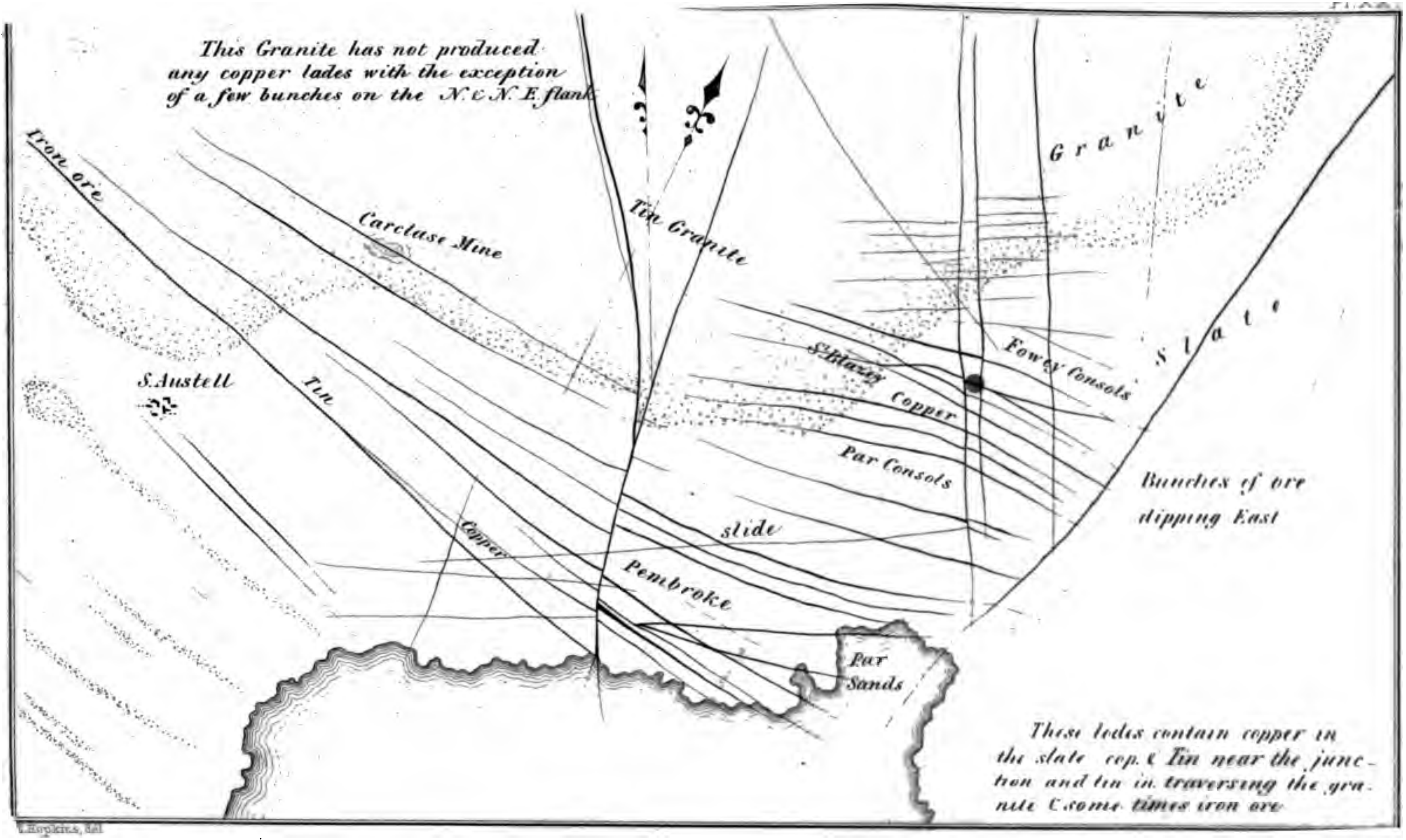
This Auriferous porphyry effervesces with acids. _ the felspar being calcareous

All the Lodes dwindle into mere joints in depth and also in an horizontal direction.

(See the Isometrical view Plate XXVI)

Explored to this depth.


The Great Consolidated Mines, Cornwall.
West
East
N underlay
Adit Level
Cross Course
Poor
Rich ground
Cross Course
Cross Course
Poor
Granite
Killas
The Devon Great Consols.
East
S underlay
W. Josiah
W. Emma
W. Maria
R. Tamar
Riv Tamar
Poor hard Gunnis
The Gt. C. Lake Course
Rich ground
Silliceous Granite
Cross Course
Schistose mineralized but dissemina-ted in the slate
Slate

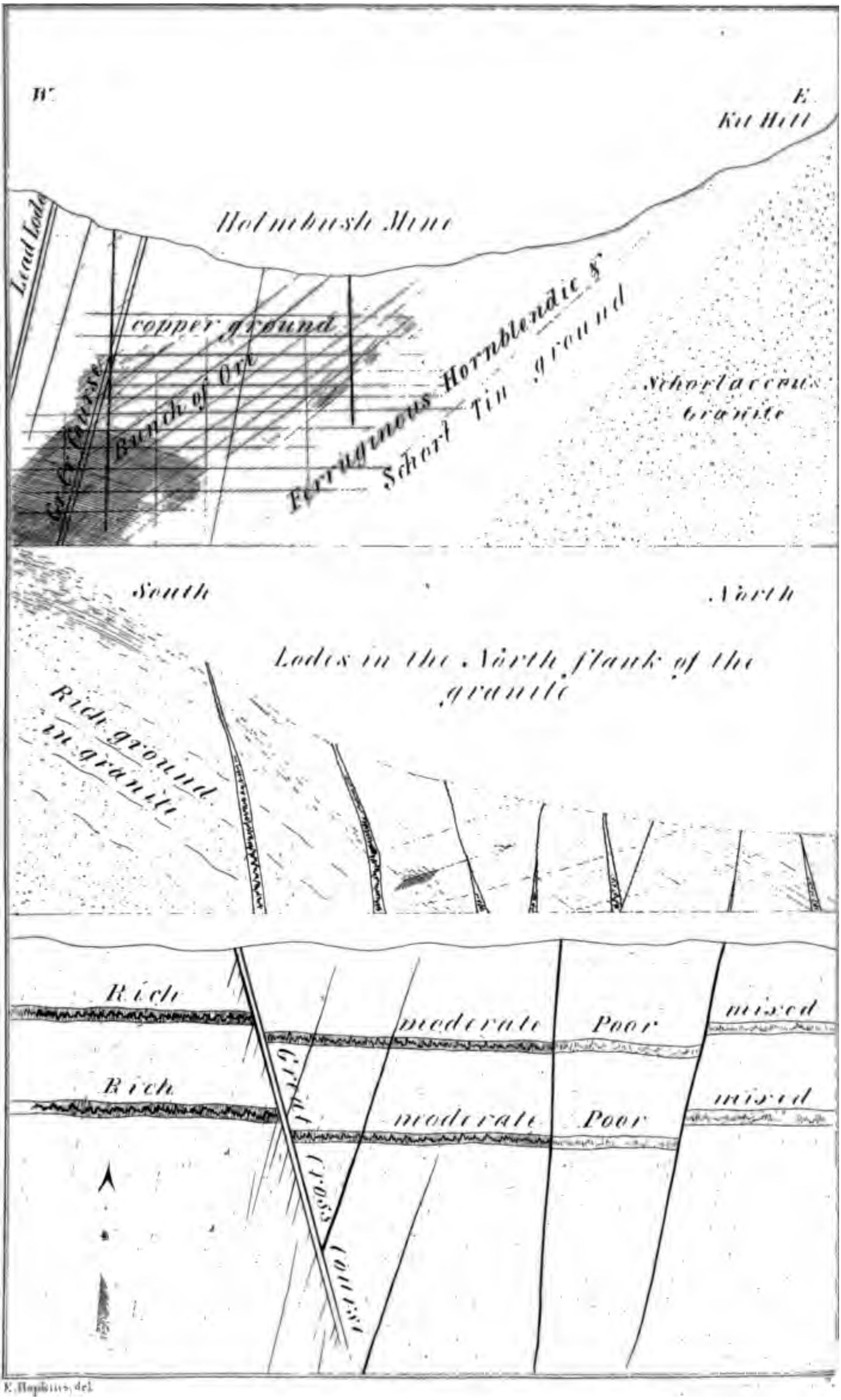


This Granite has not produced
any copper lades with the exception
of a few bunches on the N. & N. E. flank

Bunches of ore
dipping East

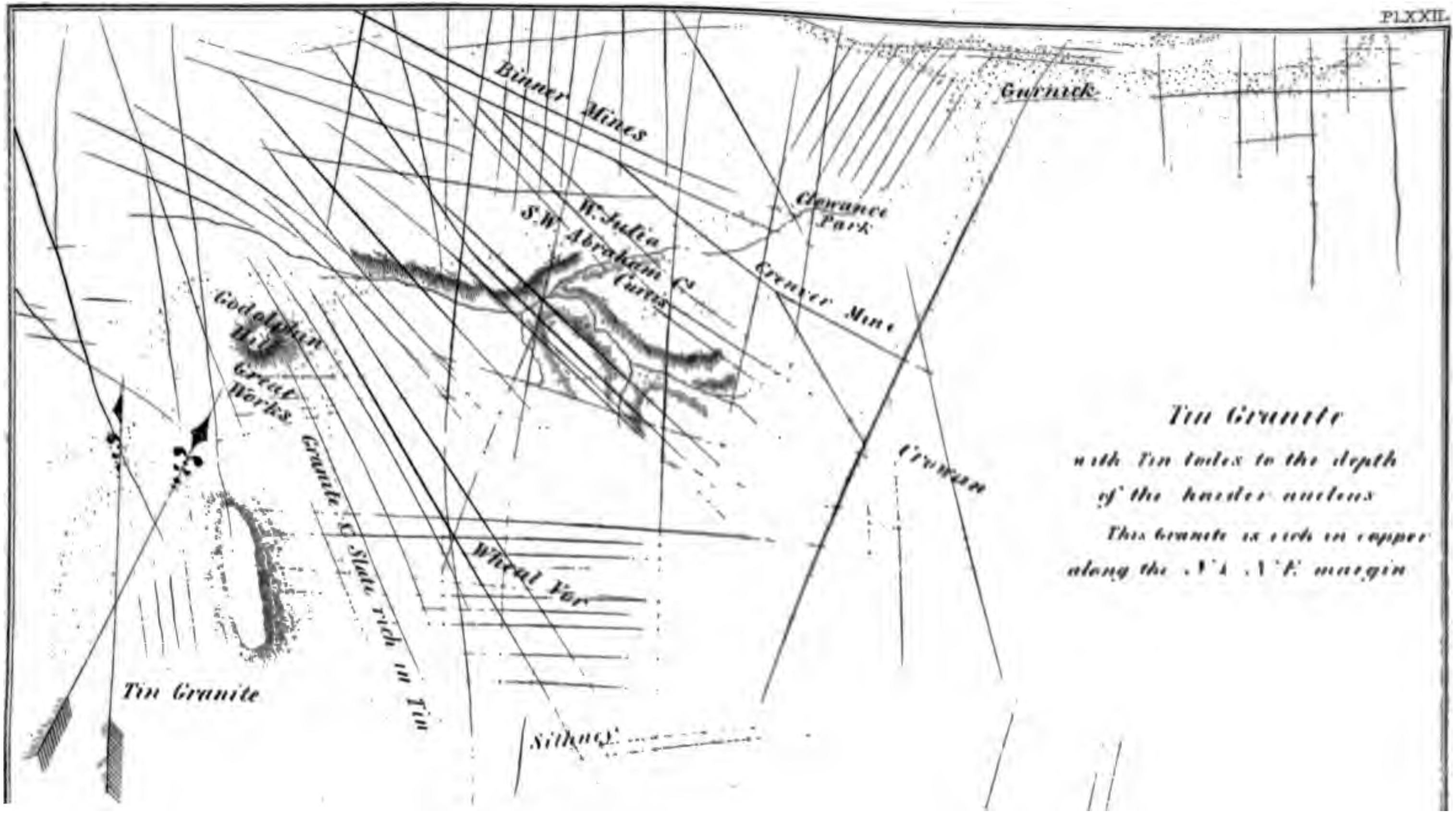
These lodes contain copper in
the slate cop. & Tin near the junction and tin in traversing the granite & some times iron ore

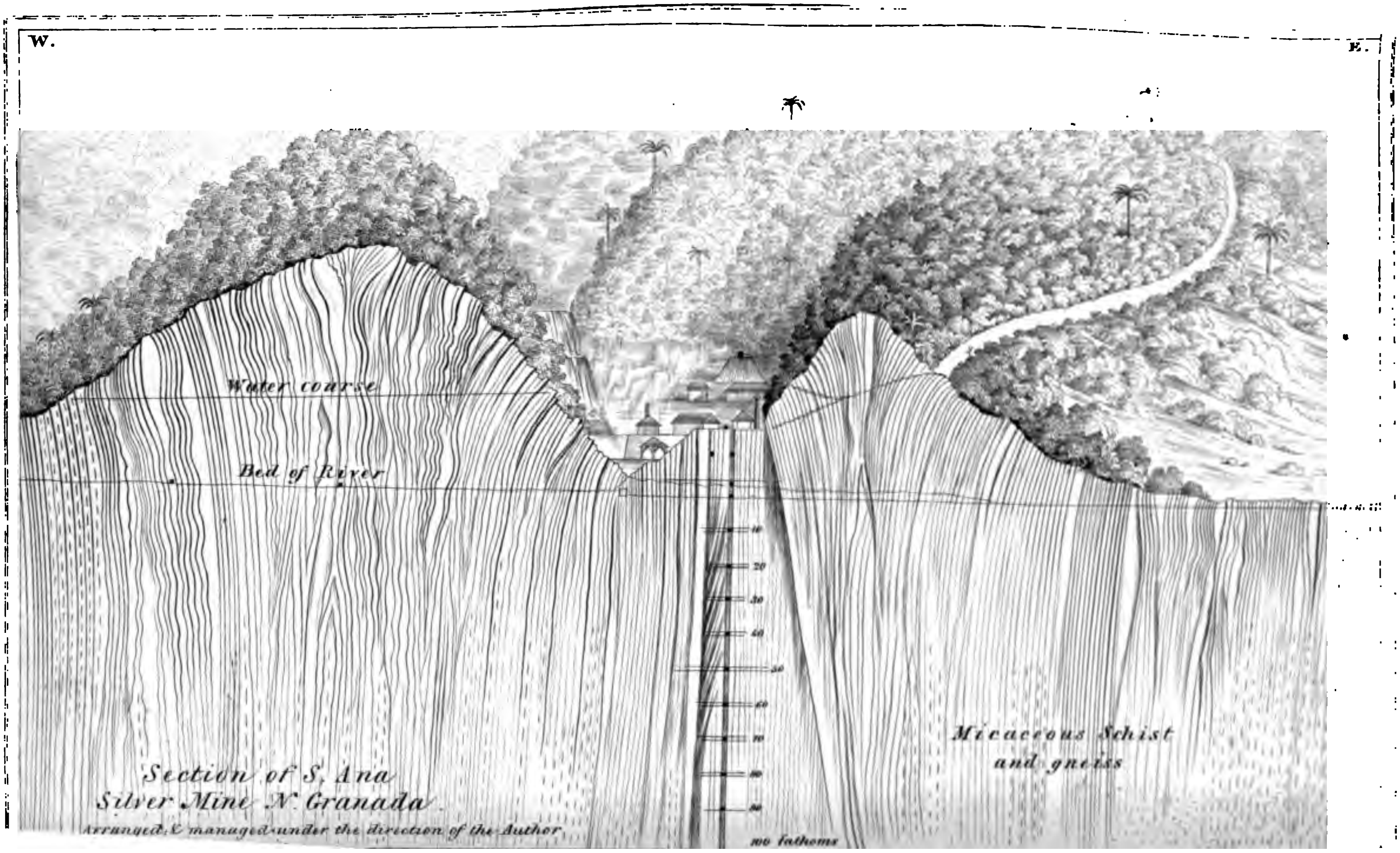
Hopkins, del



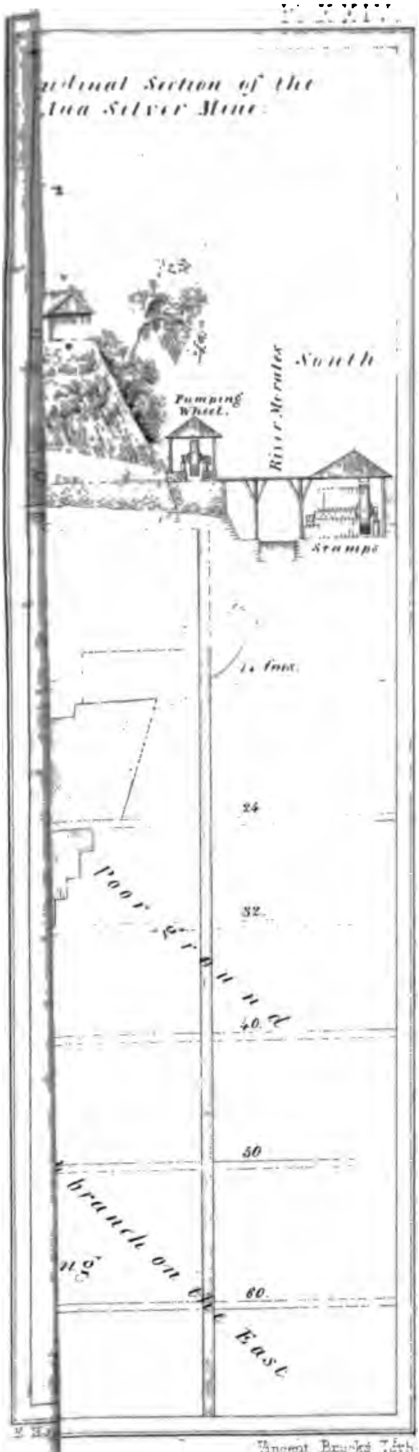
E. Hopkins, del.

PL.XXII.


Binner Mines
Gurnick
Clowance Park
W. Julia
S.W. Abraham & Curns
Crenver Mine
Godolphan Hill
Great Works
Crowan
Tin Granite
with Tin lodes to the depth
of the harder nucleus
This Granite is rich in copper
along the N.W. N.E. margin
Granite & Slate rich in Tin
Wheal Vor
Tin Granite
Sithney

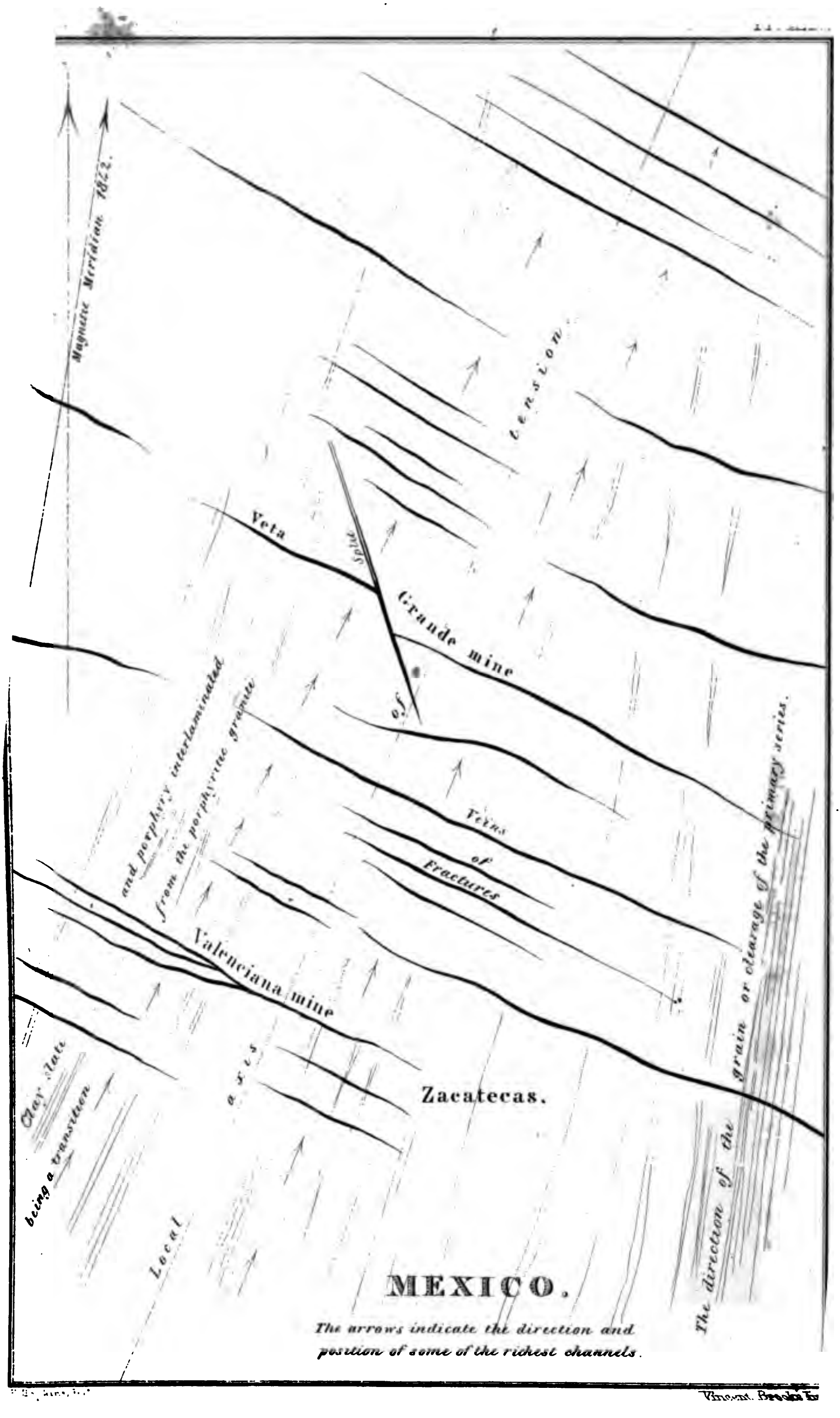


Section of S. Ana
Silver Mine N. Granada
Arranged & managed under the direction of the Author



udinal Section of the
tua Silver Mine:

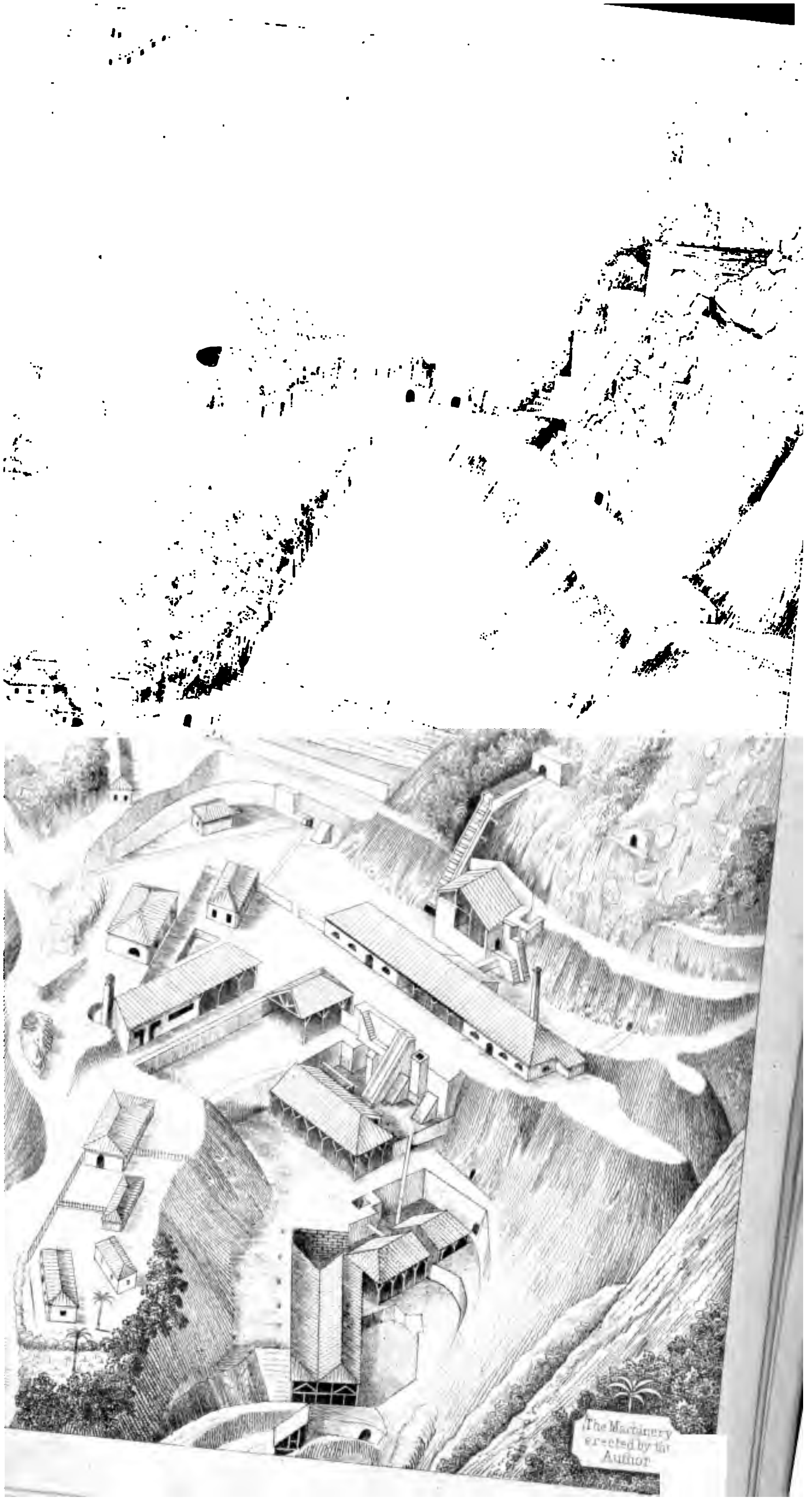
Vincent Brooks Lith


Magnetic Meridian 1842.
Veta Grande mine
Split
of
Veins of Fractures
Valenciana mine
Zacatecas.
Local axis of tension.
and porphyry interlaminated from the porphyritic granite
Clay slate being a transition
The direction of the grain or cleavage of the primary series.

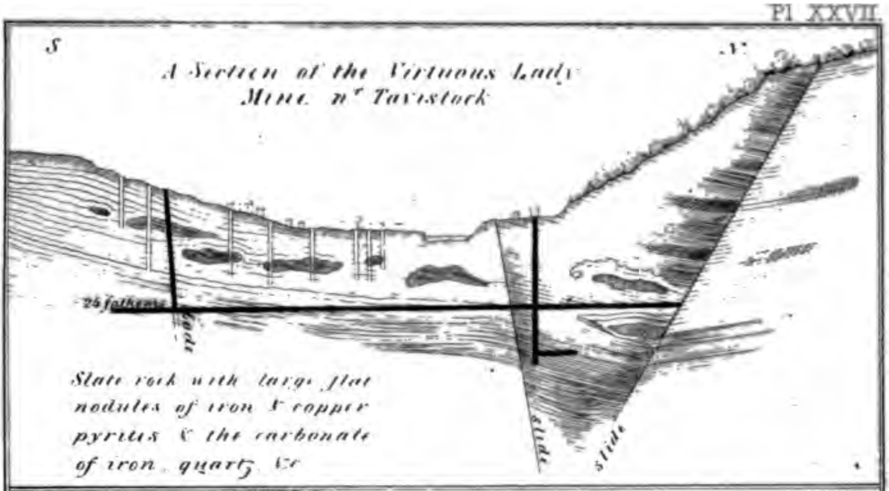
MEXICO.

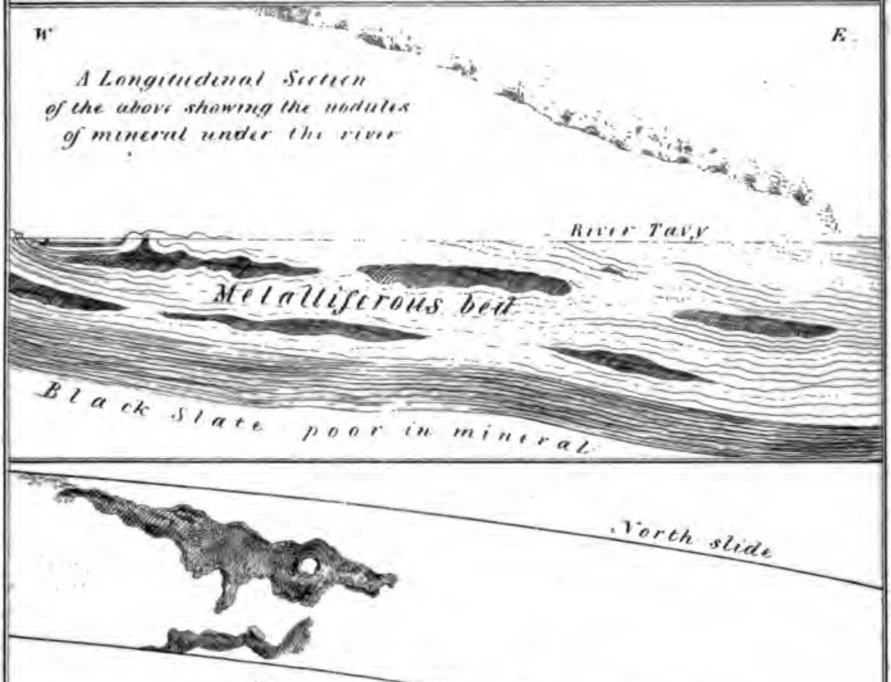
The arrows indicate the direction and position of some of the richest channels.

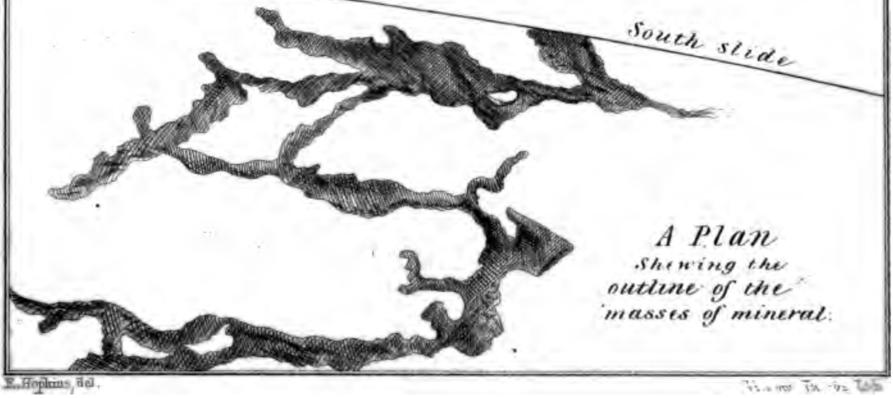
Vincent. Brooks Im.


The Machinery erected by the Author

Pl. XXVII.

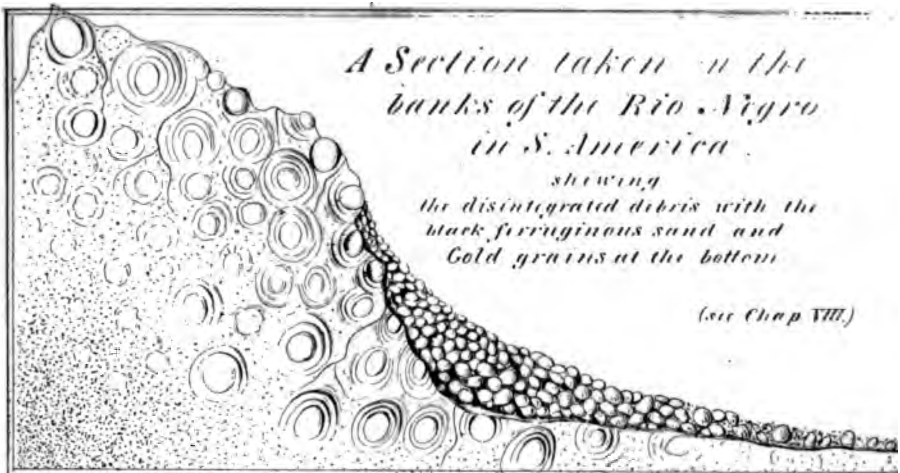

A Section of the Virtuous Lady Mine n^r Tavistock
S
N
24 fathoms
Lode
Slate rock with large flat nodules of iron & copper pyrites & the carbonate of iron, quartz &c
slide
slide


A Longitudinal Section of the above showing the nodules of mineral under the river


A Plan Shewing the outline of the masses of mineral.

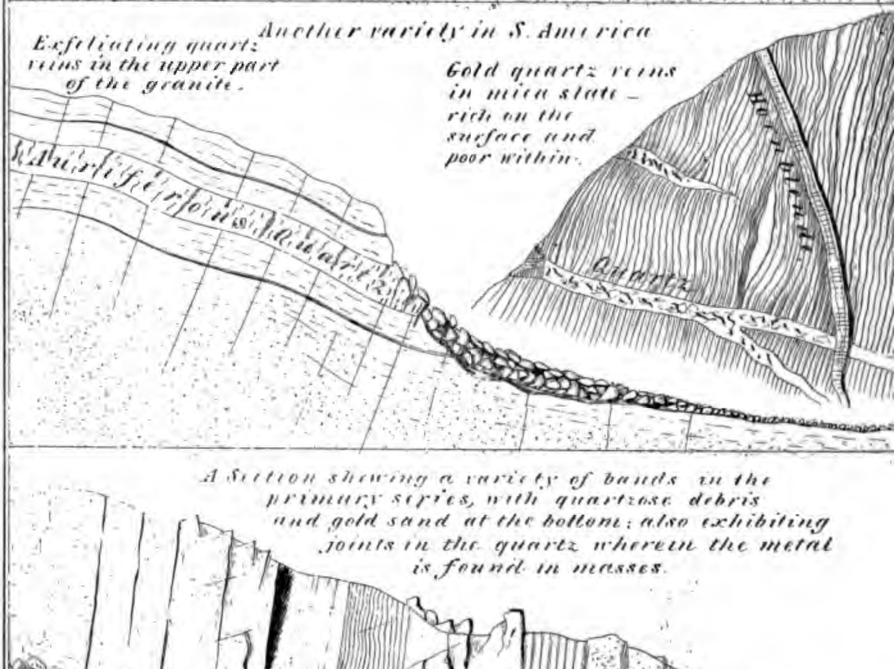
E. Hopkins, del.

[illegible] Lith



A Section taken on the banks of the Rio Negro in S. America.
shewing
the disintegrated debris with the black ferruginous sand and Gold grains at the bottom

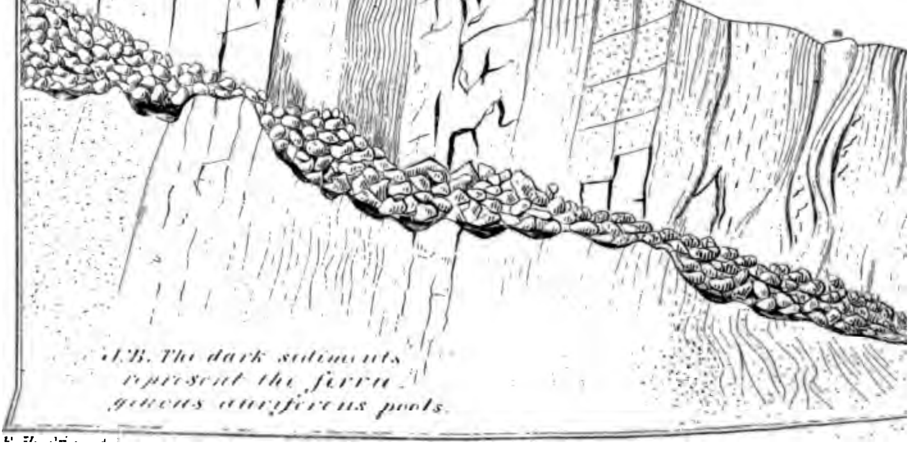
(see Chap VIII.)



Another variety in S. America

Exfoliating quartz veins in the upper part of the granite.

Gold quartz veins in mica slate – rich on the surface and poor within.



A Section shewing a variety of bands in the primary series, with quartzose debris and gold sand at the bottom; also exhibiting joints in the quartz wherein the metal is found in masses.

N.B. The dark sediments represent the ferruginous auriferous pools.

2